Scanning Thickness Measurement System

A ***Major Qualifying Project*** Report

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Abstract

As technology evolves products are designed with narrower manufacturing tolerances which require more precise manufacturing practices and testing. This project designs and implements a scanning thickness gauge for use in the sheet extrusion industry. The report discusses the need for the scanning thickness gauge and why a commercially available system was not an option. The report details the steps taken to program, interface, and implement a scanning thickness gauge using an existing thickness measurement device. The finished project is discussed including the limitations of the system and future improvements to the system.

Executive Summary

This report briefly explains the requirement for inline thickness measurement in sheet extrusion processes. The specific technical and financial requirements of the project are defined. The brief background on systems control components including the supervisory control and data acquisition (SCADA), human machine interface (HMI), and programmable logic controller (PLC) are discussed. The procedure for designing and implementing the system is detailed in smaller sub-sections that include the motion control system, thickness measurement system, SCADA, and the graphical user interface. Finally the report discusses the system limitations and possible system improvements.

The requirement for inline thickness measurement in sheet extrusion processes is growing due to the narrow product tolerances being introduced due to technological advances. As technology continues to evolve product components must be manufactured with narrower specification limits. In today's manufacturing environment quality and narrow tolerances have become a necessary part of product acceptance. In converting, calendaring, and extrusion industries the thickness of the material needs to be measured inline, as it is being produced, to guarantee product conformance.

The technical requirements of the project are based on the products and processes of the sheet extrusion line that the system will be integrated with. The products have a varying web width of 6" to 30" requiring the scanner to have an adjustable scanning area. The process speeds of the sheet extrusion line vary and will require the scanner to scan faster or slower based on the speed the web is travelling. The system must integrate an existing magnetic induction thickness gauge but allow simple integration of other type thickness gauges. The financial requirements of the system are that the total system cost is less than a quarter of the cost of similar commercially available scanning thickness measurement systems that have a price range of $50,000-150,000.

The system control components consist of the PLC, SCADA, and HMI. The PLC is a digital computer that is used for automating electromechanical processes in industrial control

systems. Programmable logic controllers can be programmed using five different languages, this project uses the most common language being ladder logic. The ladder logic consists of inputs on one side of the rungs and outputs on the other side of the rungs. The SCADA is responsible for the collection of process control data, generating alarms, communications and control. The major components of the SCADA discussed in this project are the OPC server and the process database. The OPC server is the SCADA component responsible for I/O drivers and device communications. The process database is the SCADA component that organizes process data and manipulates the data for calculations, secondary functions and internal logic. The HMI is the user interface, the point at which an operator interacts with the machine. The human machine interface could consist of a large industrial control panel filled with indicators and controls or it could be a graphical user interface (GUI). The primary responsibility of the HMI is to display process parameters and allow user entry of control instructions. This project implements a GUI for the HMI.

The system consists of four major components, the motion control system, the thickness measurement system, the SCADA system and the graphical user interface. The thickness measurement system for this project is already selected and is not discussed in depth. The focus of this report will be on the motion control system, the graphical user interface, and the SCADA system. The block diagram in Figure 1 shows the system components and how they are connected. The motion control system consists of the programmable logic controller, a DC power supply, a stepper drive, a stepper motor, a belt driven linear actuator, and 3 magnetic proximity switches for position feedback. The SCADA consists of a single block which represents a personal computer with the iFix HMI/SCADA bundle installed. The HMI/SCADA provides a communication link between the GUI and the PLC, as well as reads thickness data from the thickness gauge. The graphical user interface is a touch screen monitor that allows the user to interact with the PC displaying current values and allowing the user to input new values to control the motion system.

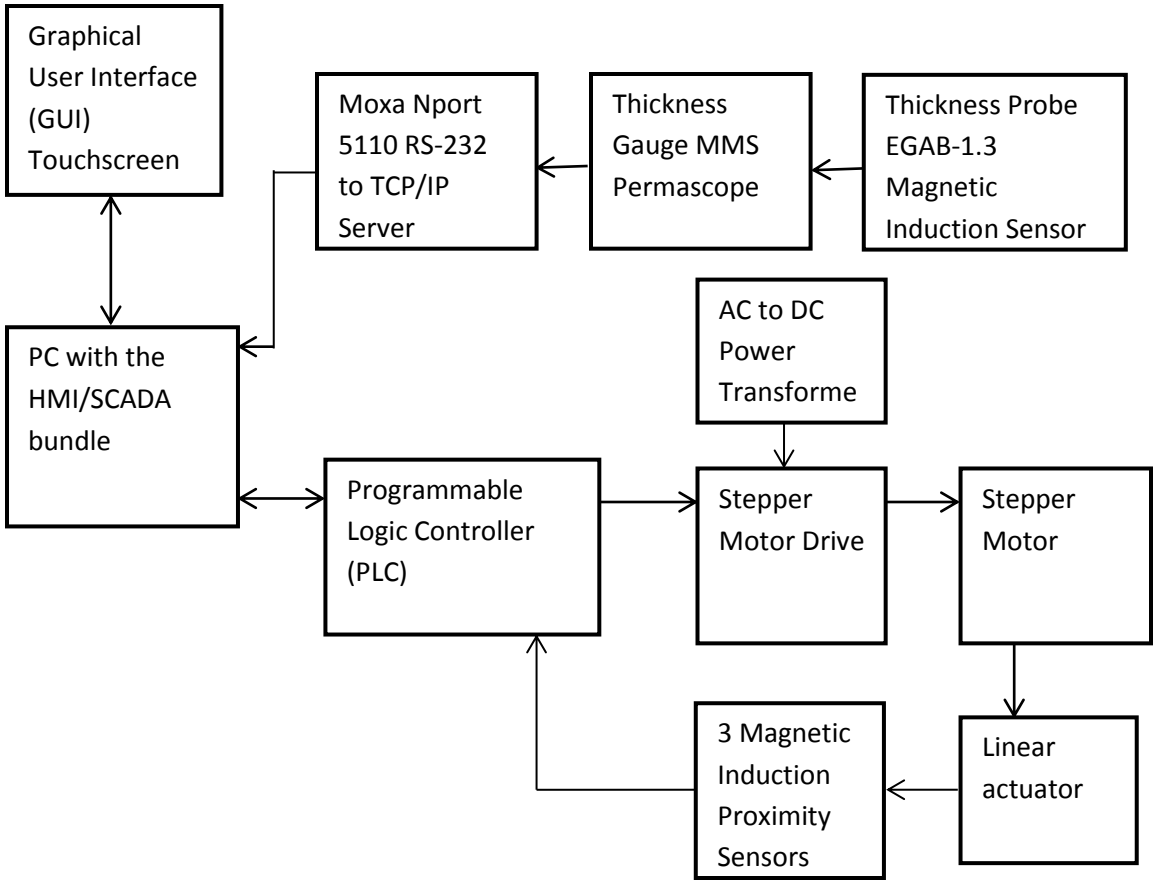
Graphical User Interface (GUI) Touchscreen
Moxa Nport 5110 RS-232 to TCP/IP Server
Thickness Gauge MMS Permascope
Thickness Probe EGAB-1.3 Magnetic Induction Sensor
PC with the HMI/SCADA bundle
AC to DC Power Transforme
Programmable Logic Controller (PLC)
Stepper Motor Drive
Stepper Motor
3 Magnetic Induction Proximity Sensors
Linear actuator

Figure 1: Block Diagram of the scanning thickness measurement system.

The motion control system is responsible for controlling the motion of the thickness scanner. The PLC receives configuration data from the SCADA and responds accordingly. The PLC outputs a clock signal to the stepper drive which uses the clock signal to change the current pulsing through the stepper motor. The stepper motor rotates turning a pulley that is connected to a belt inside of the linear actuator. The 3 magnetic induction proximity sensors provide position feedback to the PLC. One of the sensors is located in the middle of the linear actuator and acts as a registration sensor. The other two sensors are located on the two extremes of the linear actuator and act as limit switches so that the machine will damage itself.

The existing measurement system consists of the Permascope benchtop unit, a magnetic induction probe, and a steel back plate. The new measurement system will have one additional component. A serial device server will be used allowing the thickness gauge to be

connected to the SCADA PC through Ethernet. The serial device server is configured in real com mode; in this mode the PC treats the server as a com port.

The two main parts of the SCADA are the OPC server and the process database. In this project the OPC server that was used is the Industrial Gateway Server (IGS). The OPC server is used to configure “tags” that can then be added to the process database of iFix, it is responsible for the IO communications of the SCADA. When configuring the IGS the communication channel, device, and then the tags need to be configured. This project has two channels configured using serial connections, one for the PLC and one for the thickness gauge.

The process database is a major component of the SCADA which organizes process data into individual units of information. These units of information are called “tags.” The tags can interact with the OPC server reading and writing data to the control hardware. The process database can also manipulate the data for calculations, secondary functions and internal logic. There are many different block types available in the process database, these are separated into three categories primary, secondary and batch blocks. The primary blocks are inputs, outputs, and registers, these blocks can stand alone and have the ability to read from or write to a Driver Image Table (DIT). The secondary blocks receive and send data to and from other tags, not from the Driver Image Table. These tags cannot be stand-alone tags and have to be part of a chain that starts with a primary tag. Secondary tags typically perform calculations and logic with data retrieved from a primary block. The program block is not a primary block or secondary block, these are special blocks known as batch blocks. These blocks are stand-alone blocks that can execute simple 20 line programs to help with internal database actions and logic, allowing additional automation options for various processes.

The graphical user interface allows users to interact with the machinery, equipment, and electronic devices. The graphical user interface uses a non-text based display made up of buttons, icons, and other visual indicators. The hardware of the graphical user interface is a touchscreen monitor. The iFix HMI software is used to develop the on screen visuals of the GUI. Development of the iFix HMI consists of linking analog tags to data stamps, digital tags to onscreen buttons, and generating animations as needed. The major challenge of this project

was generating a chart to show a real time thickness profile. This was accomplished through use of animations that were linked to thickness data tags.

Although the system has been completed there is still more work to be done. The system as it stands has a few issues and opportunities for improvement. The first issue is that the thickness value varies depending on the direction the scanner is travelling in. This will need to be investigated and then corrected as it has a direct impact on the accuracy of the thickness profile that is displayed. A second issue that needs to be corrected is an intermittent animation problem that causes the chart columns to disappear for a single pass of the scanner. A third issue with the system is that some of the columns in the chart are updated multiple times as the scanner passes them, while others are missed. The column update problem may be corrected by adjusting scan times of the programming blocks.

The first improvement that needs to be made to the system is to increase the accuracy of the thickness measurements. This may be accomplished by correcting issues with the current measurement system. However there are other thickness measurement techniques that would provide an increased precision and accuracy. With this system the thickness gauge can be easily replaced by establishing communication with the new thickness gauge and replacing the data source for the THICKNESSRAW tag. The second step for improving the thickness scanner will be to link the thickness tags to a Historian server. Once the tags are being collected in a Historian server the data can be queried and trends for machine direction variation can be examined further increasing the usefulness of the scanner. The third step would be to expand the graphical user interface adding different types of charts that can be used for statistical process control. The charts that may be implemented include a historical display indicating the historical thickness data regardless of position, a histogram showing the thickness distribution, and machine direction thickness charts indicating the historical thickness for specific scanner positions. One last improvement may be to increase the resolution of the thickness profile chart with columns representing less than one quarter of an inch.

Acknowledgements

I would like to thank Professor Bitar for his support in the completion of this Major Qualifying Project. Professor Bitar was always willing to spend time working through the various technical problems offering suggestions on how to approach the different problems that I was confronted with throughout the project. I would also like to thank Professor Bitar for setting high expectations while still being flexible with the work load and understanding of my other obligations.

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1 Introduction

As technology continues to evolve product components must be manufactured with narrower specification limits. In today's manufacturing environment quality and narrow tolerances have become a necessary part of product acceptance. In converting, calendaring, and extrusion industries the thickness of the material needs to be measured inline, as it is being produced, to guarantee product conformance.

This project takes on the task of designing and implementing a scanning thickness gauge for a sheet extrusion line. The design will incorporate an existing thickness gauge, the Fischerscope MMS Permascope, into a scanner that is controlled through a graphical user interface (GUI). The system will be designed with future improvements in mind including easy integration of other thickness gauges. The extrusion line runs many different products with different web widths. The web widths vary from 6" to 30" and the scanner will have to be adjustable to scan the varying web widths without traversing off the web. The web speed also changes depending on the product, the scanner will have an adjustable speed to compensate for the varying web speed. The position data of the scanner and the thickness data from the Permascope will be collected and then translated into a thickness profile display. The thickness profile showing the position data on the x-axis and the corresponding thickness on the y-axis is the primary display that will be implemented. The major reason for this project is that the cost of a thickness scanning system is very high and this project attempts to implement a scanning thickness gauge with a cost that is approximately ¼ the cost of existing thickness scanners. The major problem with existing scanning thickness gauge systems is high costs, a lot of these costs are due to engineering costs of the custom made systems. These systems currently cost from $50,000 to $150,000, this cost range was determined through having a half dozen companies quote a scanning thickness measurement system during the first half of 2013.

2 Background

The scanning thickness gauge is not a new concept, these devices are used in many industries. Scanning thickness gauges are used in the plastics, metals, paper, nonwovens, textiles, and converting industries [1]. In all of these industries there is a need to measure the thickness of the product as it is being made or converted. A scanning thickness gauge measuring a sheet of film is shown in Figure 1 [2].

Figure 1. NDC brand scanning thickness gauge retrieved from the NDC website[2].

An important and maybe the most important part of the scanning thickness gauge is the method of measuring the thickness of the material. As seen in Table 1, there are many different methods and technologies for measuring the thickness of a material [3]. Some of these methods can be adapted to a scanning thickness gauge but there is not one method that is the best, they all have positives and negatives. The various aspects that need to be considered in selecting the thickness gauge are the material type being measured, resolution, range, spot size, and collection speed. Another consideration is whether the gauge can be contact or if it needs to be a non-contact measuring device.

Technique	Range	Comments
Mechanical		
Caliper gage, micrometer	1 μm–100 mm	±3 μm accuracy
Electronic gages: LVDT	0–1 m	Precision depends on noise level
Pneumatic gaging	50 nm minimum	
Optical/focusing, shadowing, comparing		
Microscope	5 μm minimum	About 1% accuracy
Comparators/projectors	25–250 mm	
Laser caliper	100 μm–100 mm	Precision of 6 μm or better
Weighing	Range depends on area	
Capacitive gaging	From <1 μm to about 1 cm	
Inductive gaging (eddy current sensing)	0–1.5 mm	Precision of 2.5 μm
Magnetic induction	0–4 mm	10% accuracy
Hall effect gage	0–10 mm	1–3% accuracy
Far-field/time-of-flight		
Sonar/ultrasound	0.5–250 mm	25 μm accuracy
Radar	0.1 to few hundred km	
Lidar	10 m–5 km	
THz technology		
Far-field/resonance		
Resonant ultrasound		
Interferometry: spectral and spatial	1 nm–100 μm	Accuracy about λ/50
Ellipsometry	0.3 nm–10 μm	0.1 nm accuracy
Far-field/absorption, scattering, emission		
Gamma-ray backscatter	Range to 25 mm	0.5% precision
Beta-transmission	2 μm–1 mm	0.2% precision
Beta-backscatter	100 nm–50 μm	3 to 20% precision
X-ray fluorescence	0–30 μm	
Infrared absorption	Depends on material	
Scanning techniques: scanning probe microscopy		Precision better than 0.1 nm
Destructive techniques: electrolytic	15 nm–50 μm	

Table 1: Thickness Measuring Techniques [3]

One of the major considerations in designing a thickness scanner is the material that will be measured. One measuring method may produce the best results for one material but the worst for another material. This project will focus on generating a thickness scanner for an extruded film that can be foamed or solid. The film surface is not critical and does not require the thickness gauge to be a non-contact method.

The next important part of the scanning thickness gauge is the motion system. The motion system consists of a single axis motion as the thickness gauge is moved back and forth across the web. Typically these systems are made up of a drive, motor, and translational device. The translational device converts the rotational motion of the motor into linear motion. These devices are usually belt driven for speed or ballscrew driven for accuracy. Most scanning thickness gauges use a belt driven linear actuator to capture more of the cross web thickness.

The last part of a scanning thickness gauge is the control system that will be used for controlling the motion system, collecting the thickness measurements, and displaying the thickness profile. There are many different ways to implement the control system but all scanning thickness gauges contain a motion controller that communicates with the motion systems drive and a human machine interface (HMI) that displays data and takes inputs. This part of the scanning thickness gauge will be the focus of this project.

2.1 Supervisory Control and Data Acquisition (SCADA) systems

The SCADA platform is one of the most important decisions that need to be made when designing an industrial control system. In the case of this project the SCADA platform that will be used is iFix version 5.5. This decision was made because iFix is the standard SCADA platform used on our equipment. Standardization of industrial control systems and SCADA is important to reduce operation and maintenance costs. Table 2 shows other vendors that provide SCADA platforms and the names of the SCADA platforms [4:161]. The original decision of which SCADA platform to use was made by comparing the different platforms. We found that Wonderware and iFix were similarly flexible. The decision between these two platforms was inconsequential and iFix was selected as our SCADA platform.

Manufacturer	**Current SCADA Platform**
ABB	SCADAvantage
ACS	Prism
Alstom	Windaccess, e-terrascada
C3-Ilex	EOScada
CG automations	TDMS-Plus
Citect	CitectSCADA
Foxboro	Invensys
GE Fanuc Automation	iFix 32
Indusoft	Web Studio
Motorola	MOSCAD
Wonderware	ArchestrA wonderware platform

Table 2:Major manufacturers and current SCADA systems, table from Project Management Phases of a SCADA System for Automation [4:161], updated by Ray Stockwell

The SCADA is responsible for the collection of process control data, generating alarms, communications and control [5:1-3]. The SCADA records process control data into a local or server Historian. The SCADA development flowchart from the iFix training manual is shown in Figure 2 [5:1-10].

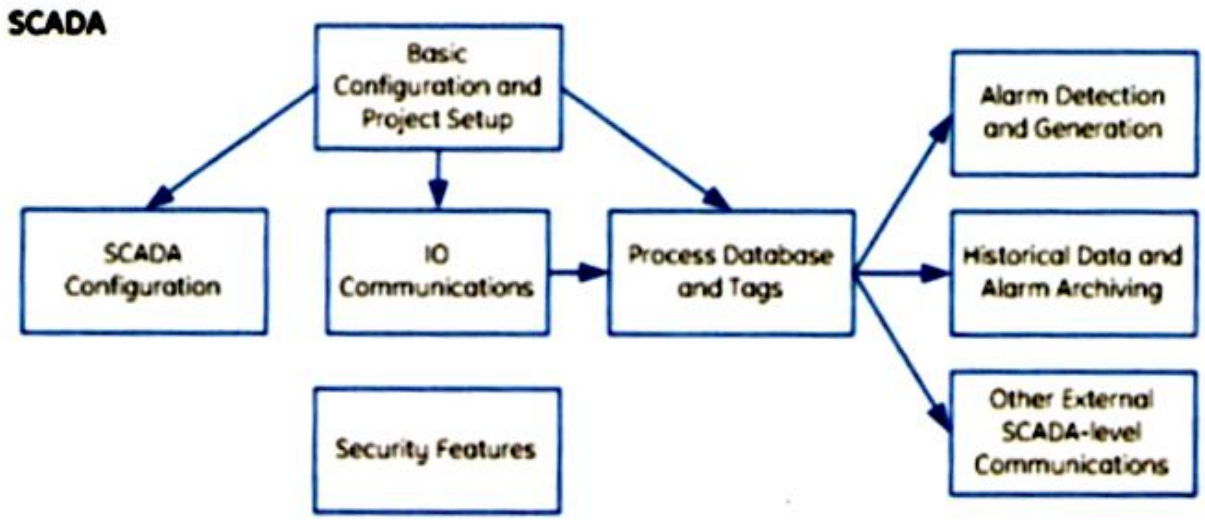

Figure 2: SCADA Application Development Flowchart [5:1-10]

2.2 Human Machine Interface (HMI)

The human machine interface is the user interface, the point at which an operator interacts with the machine. The human machine interface could consist of a large industrial control panel filled with indicators and controls or it could be a graphical user interface (GUI). The primary responsibility of the HMI is to display process parameters and allow user entry of control instructions. The HMI can display alarms if process values are beyond preset process limits. The HMI development flowchart from the iFix training manual is shown in Figure 3 [5:1-10].

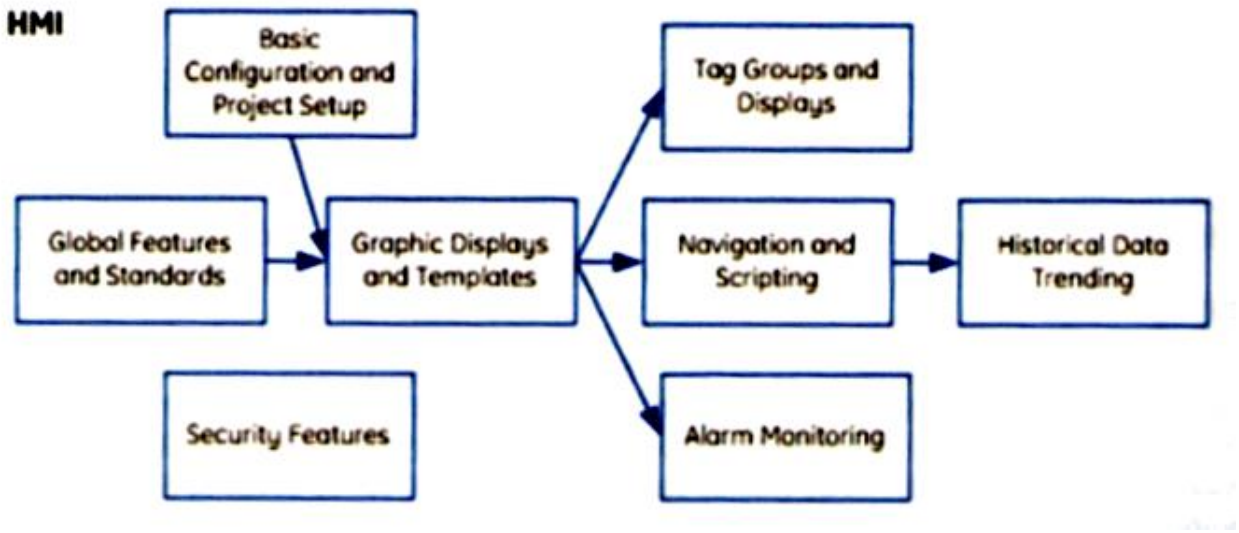

Figure 3:HMI Application Development Flowchart [5:1-10]

2.3 Programmable Logic Controllers (PLC)

The PLC is a digital computer that is used for automating electromechanical processes in industrial control systems. PLCs can be programmed using one of five different languages, structures text (ST), instruction list (IL), sequential function chart (SFC), function block diagram (FBD), or ladder diagram (LD) [6]. The ladder logic consists of inputs on one side of the rungs and outputs on the other side of the rungs. An example of a single rung from a ladder diagram can be seen in figure 4 [7].

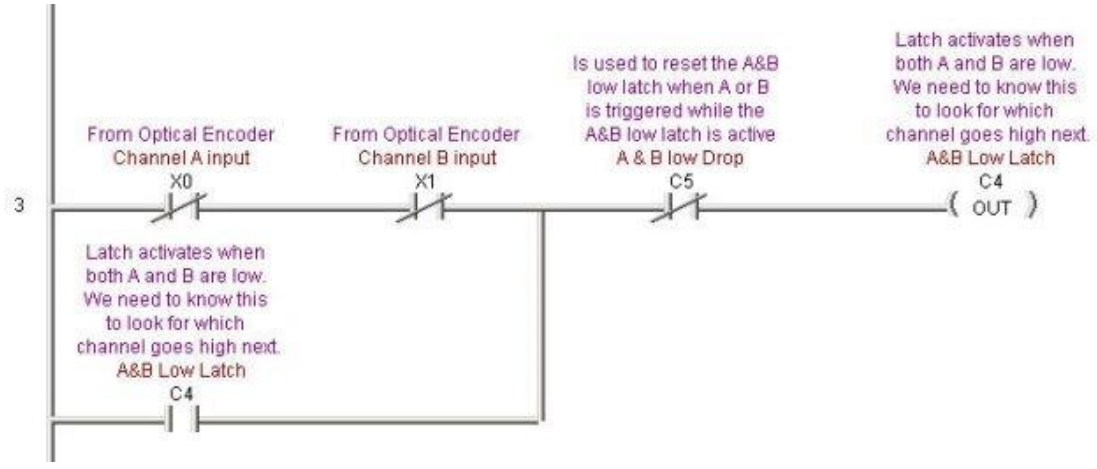
3
From Optical Encoder Channel A input
X0
From Optical Encoder Channel B input
X1
Is used to reset the A&B low latch when A or B is triggered while the A&B low latch is active A & B low Drop
C5
Latch activates when both A and B are low. We need to know this to look for which channel goes high next. A&B Low Latch
C4
OUT
Latch activates when both A and B are low. We need to know this to look for which channel goes high next. A&B Low Latch
C4

Figure 4. Example of a single rung of a ladder diagram [7]

The PLC repeatedly scans the I/O, executing the program from the first rung to the last rung of the ladder logic [6]. The input criterion provides the logic for executing the outputs of the program. The inputs can be from process sensors or from user input.

Figure 5. Direct Logic 05 microbric programmable logic controller[8]

2.4 The Relationship between SCADA, HMI, and PLC

These three components are commonly used together for industrial control systems. The PLC can store instruction and implement logic, sequencing, timing, and counting functions in order to control machines and processes. [9:3] The SCADA system uses an OLE (Object Linking and Embedding) for process control (OPC) server to communicate between the PLC and the HMI[10:35]. Configuring the OPC server consists of selecting the appropriate drivers for communicating with devices, and generating the “tags” that are used for data collection and configuring the HMI. In the case of a PLC, tags are linked to the PLC memory addresses and then given descriptive names. The HMI is configured using the tag names either displaying the value from the address or allowing the user to input a value to be written to the address.

3 Procedure

In sheet extrusion there is a need to measure the thickness of the sheet so that machine adjustments can be made as necessary to maintain a uniform sheet thickness. Different machine adjustments can be made to correct thickness variation in the machine direction (MD) or the transverse direction (TD). This project takes on the task of specifying and implementing a scanning thickness gauge that can be used for measuring the thickness of a foamed polypropylene sheet and displaying a thickness profile. The sheet extrusion line that the thickness scanner will be installed on has a maximum web width of 30 inches. The sheet material is either a closed pore foam or non-foamed polypropylene sheet with thickness ranging from 2-20 mils.

The extrusion line has an existing Permascope MMS thickness measurement system that has to be incorporated into the scanner. With the Permascope MMS bench top unit having a retail value of $9,500, it has been made a design requirement that it is used in the scanning system. This thickness gauge uses a magnetic induction probe that rides on top of the sheet measuring the displacement from a steel backing. This system works well on foamed product because it is not affected by the air pockets within the plastic sheet. If possible the probe may be replaced to increase the accuracy of the measurement system. There may be a desire to replace this unit with a different thickness measurement technology in the future. This adds an additional design requirement that other sensors can be easily integrated into the scanning system.

There are other displays that may be implemented including a historical display indicating the historical thickness data regardless of position, a histogram showing the thickness distribution, and machine direction thickness charts indicating the historical thickness for specific scanner positions.

3.1 System Overview

The system consists of four major components, the motion control system, the thickness measurement system, the SCADA system and the graphical user interface. The thickness measurement system for this project is already selected and will not be discussed in depth. The focus of this report will be on the motion control system, the graphical user interface, and the SCADA system. The block diagram in Figure 6 shows the system components and how they are connected. The motion control system consists of the programmable logic controller, a DC power supply, a stepper drive, a stepper motor, a belt driven linear actuator, and 3 magnetic proximity switches for position feedback. The SCADA consists of a single block which represents a personal computer with the iFix HMI/SCADA bundle installed. The HMI/SCADA provides a communication link between the GUI and the PLC, as well as reads thickness data from the thickness gauge. The graphical user interface is a touch screen monitor that allows the user to interact with the PC displaying current values and allowing the user to input new values to control the motion system.

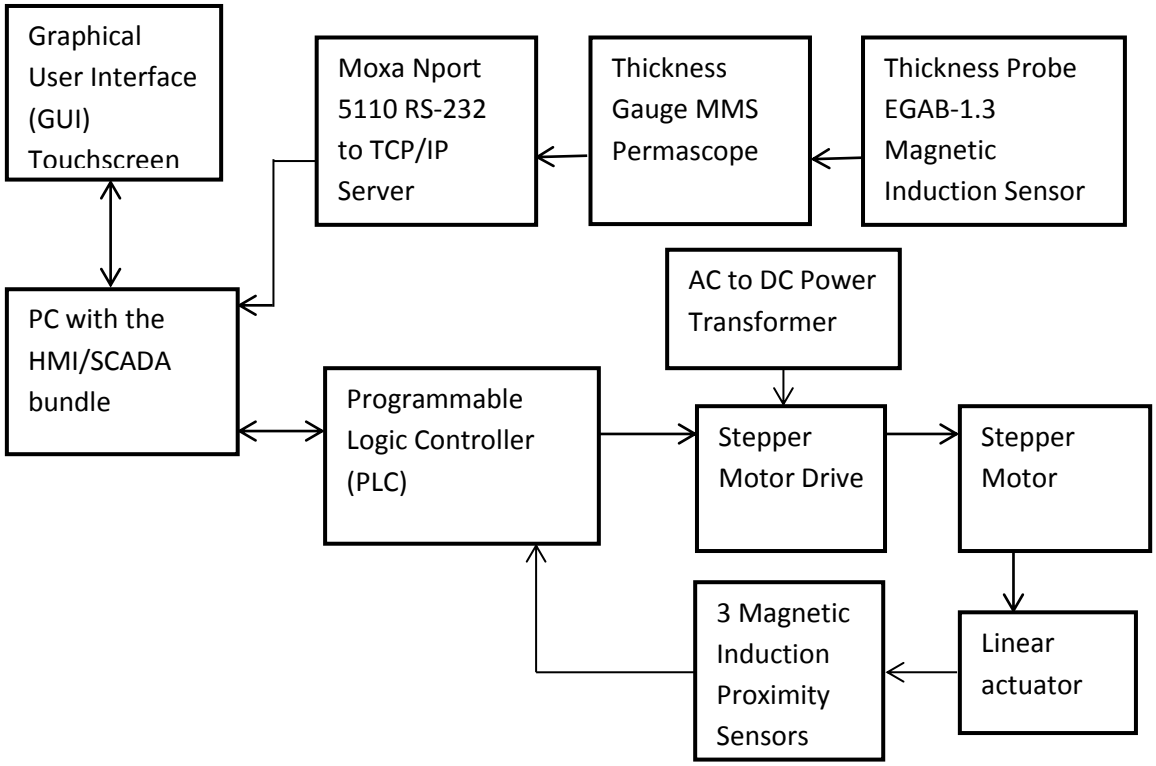
Graphical User Interface (GUI) Touchscreen
Moxa Nport 5110 RS-232 to TCP/IP Server
Thickness Gauge MMS Permascope
Thickness Probe EGAB-1.3 Magnetic Induction Sensor
AC to DC Power Transformer
PC with the HMI/SCADA bundle
Programmable Logic Controller (PLC)
Stepper Motor Drive
Stepper Motor
3 Magnetic Induction Proximity Sensors
Linear actuator

Figure 6. Block diagram showing the system components

3.2 Motion Control System

The motion control system is responsible for controlling the motion of the thickness scanner. The PLC also receives configuration data from the SCADA and responds accordingly. The PLC outputs a clock signal to the stepper drive which uses the clock signal to change the current pulsing through the stepper motor. The stepper motor rotates turning a pulley that is connected to a belt inside of the linear actuator. The 3 magnetic induction proximity sensors provide position feedback to the PLC. One of the sensors is located in the middle of the linear actuator and acts as a registration sensor. The other two sensors are located on the two extremes of the linear actuator and act as limit switches so that the machine will damage itself.

Programmable Logic Controller (PLC)

The programmable logic controller is the center of the motion control system, in this system the Automation direct, Koyo direct logic 05 plc D0-05DD with pulse output was selected. This is an inexpensive PLC at $125 and has the capability to generate the pulse outputs that are needed. There are 6 DC sinking outputs with two configurable for pulse outputs and 8 DC inputs that are configurable in blocks of 4 for sinking or sourcing. The PLC is able to generate pulse outputs because it contains a HSIO circuit. A schematic of the HSIO circuit connections is shown in Figure 7.

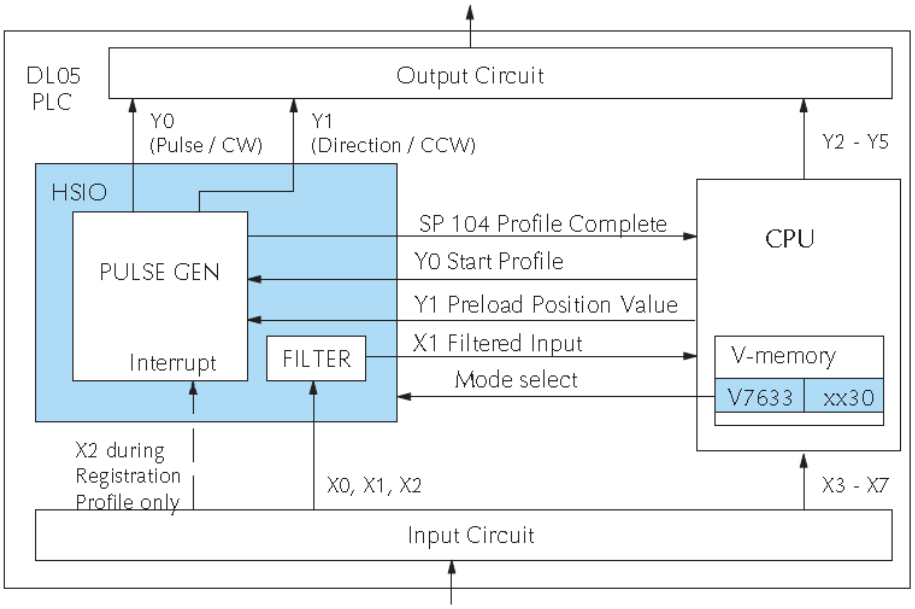

Figure 7. DL05 Functional block diagram showing HSIO functionality in mode 30[11:E-25]

The HSIO is configurable for 6 different modes. In the case of controlling a stepper motor the mode needs to be set for mode 30: Pulse Output. In Mode 30:Pulse Output the HSIO circuit generates "output pulse trains suitable for open-loop control of a single-axis motion positioning system[3:E-24]." The HSIO will generate pulse and direction signals that can be connected to the stepper drive to control the motion of the stepper motor. The HSIO can be configured to generate three different motion profile types. The three profile types are the Trapezoidal, Registration, and the Velocity control profiles. The trapezoidal profile has an acceleration slope, a target velocity, and a deceleration slope as shown in Figure 8.

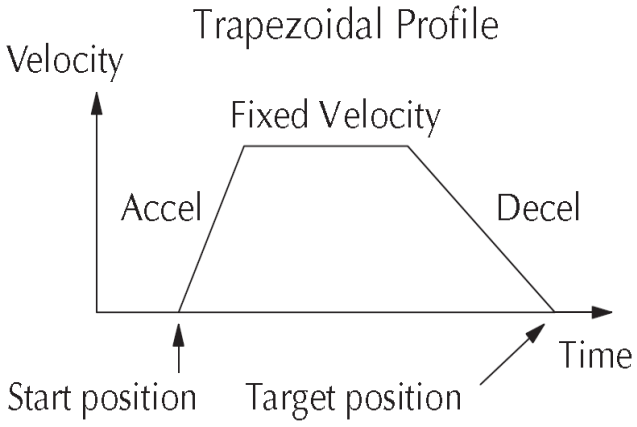

Figure 8. A diagram showing the Trapezoidal Profile [11:E-30]

The registration profile is a combination of velocity profile and position profile. The registration profile begins with velocity control and runs until the PLC receives a signal on the registration input X2, the profile then changes to a position control running for a set number of pulses after the registration signal. A diagram of the registration profile can be seen in Figure 9.

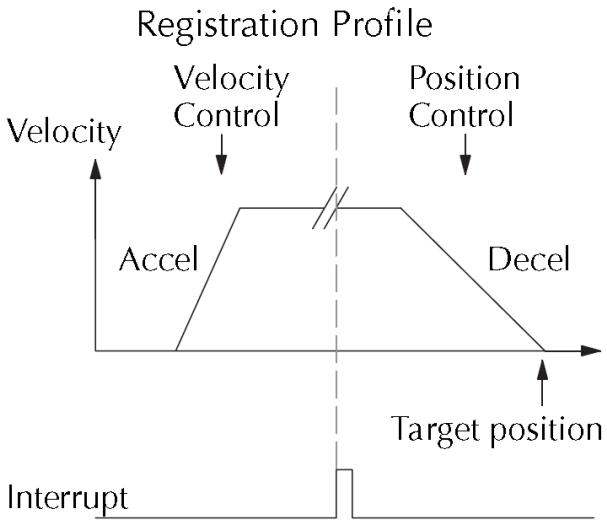

Figure 9. A diagram showing the Registration Profile [11:E-30]

The velocity profile shown in Figure 10, does not offer any position control but can alter the velocity of the stepper throughout the move.

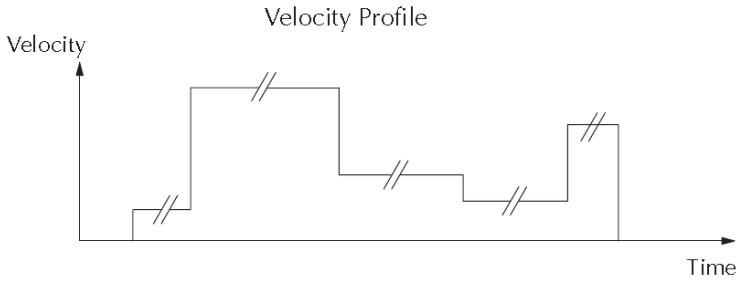

Figure 10. A diagram showing the Velocity Profile [11:E-40]

The PLC program for this project consists of Relay Ladder Logic (RLL) as well as using function blocks. The relay ladder logic is a series of rungs with inputs on the left side and outputs on the right side. The PLC CPU scans the rungs and activates the outputs based on the

inputs that are active. The input side of the rungs can contain normally open or normally closed inputs, coils, or outputs. When the inputs are activated in such a way that the circuit is completed the outputs will become activated. There are many different types of outputs and functions that can be activated on the right side of the rungs. For example the output can be used to “SET” an input, coil, or output, “RST” an input, coil, or output, or “PD” an input, coil, or output. The SET command activates the input, coil, or output until a RST (reset) command is issued. The PD command stands for positive differential and acts as a one shot setting the input, coil or output for one scan of the ladder logic.

Along with activating and deactivating inputs, coils, and outputs, the right side of the rung can contain load and out commands used for entering data values into the V-memory registers of the PLC. A special relay SPO is a one shot input that is active on the first scan of the ladder logic, when the PLC is powered on. The SPO is used to load values into the V-memory registers of the PLC and set certain outputs on the first scan. The HSIO circuit uses the values stored in the V-memory registers that are tied to a motor profile table. Table 3 shows the V-memory registers and values used for the Trapezoidal profile.

Trapezoidal Profile

V-Memory	Function	Range	Units
V2320, bits 12 – 15	Trapezoidal Profile	0=absolute, 8=relative	–
V2320,	Target Velocity Value	4 to 700	x 10 pps
V2321/2322	Target Position Value *	–8388608 to 8388607	Pulses
V2323	Starting Velocity	4 to 100	x 10 pps
V2324	Acceleration Time	1 to 100	x 100 ms
V2325	Deceleration Time	1 to 100	x 100 ms
V2326	Error Code	(see end of section)	–

* To set a negative number, put 8 in the most significant digit. For example: 8388608 is 88388608 in V2321 and V2322.

Table 3. Motor Profile table for a Trapezoidal Profile [11:E-29]

One of the difficulties in using the D0-05DD and the HSIO circuit is that changes to the motion profile cannot be made dynamically. The HSIO circuit runs the motor profile while the CPU of the PLC continues to scan the ladder program. This is allows the PLC CPU to continue accepting inputs and triggering outputs, however the HSIO will complete its profile before accepting any changes to the motor profile table. This means that in order for the HSIO to run a

new motor profile table the motor needs to be stopped or must have already completed the motor profile.

The RLL program for this project is based on three major functions, a homing function, an autoscanning function, and a manual scanning function. The homing function is used to locate the registration sensor and set the current position to zero. A flow chart showing the operation of the homing function is shown in Figure 11.

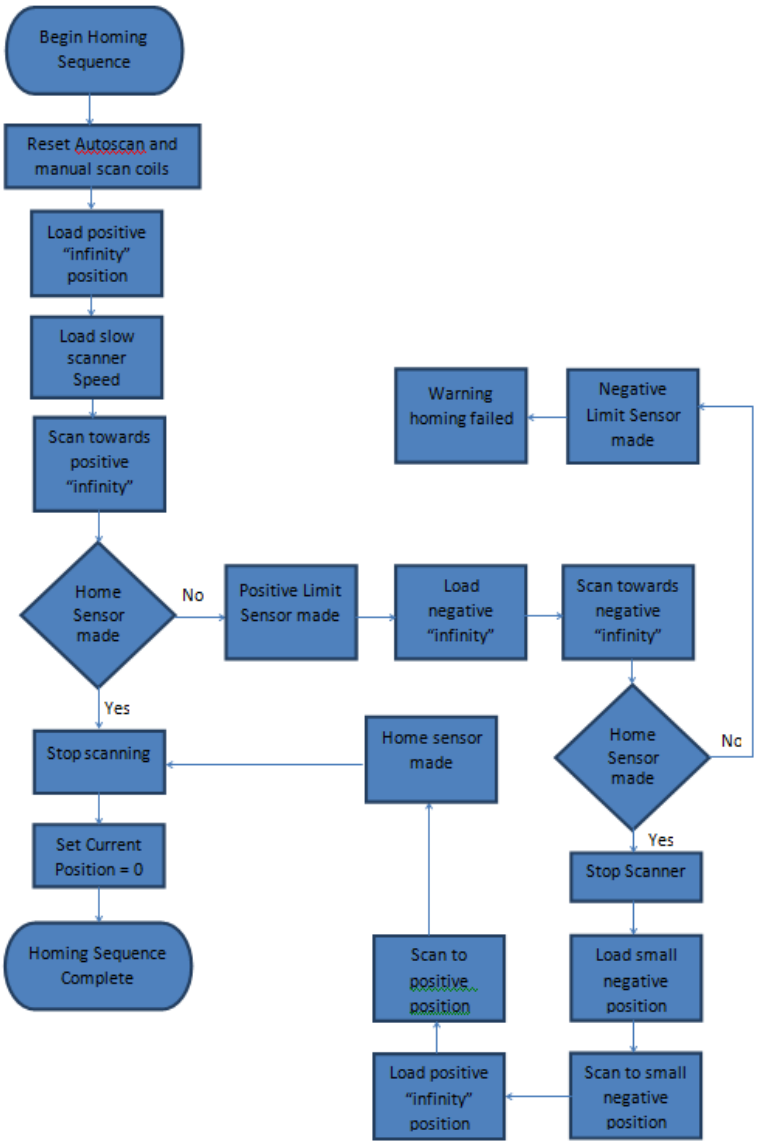

Figure 11. A Flow chart showing the homing sequence of operations.

The autoscanning function is the primary function and is used to scan back and forth between two locations that are set by the user. A flow chart showing the operation of the autoscanning function is shown in Figure 12.

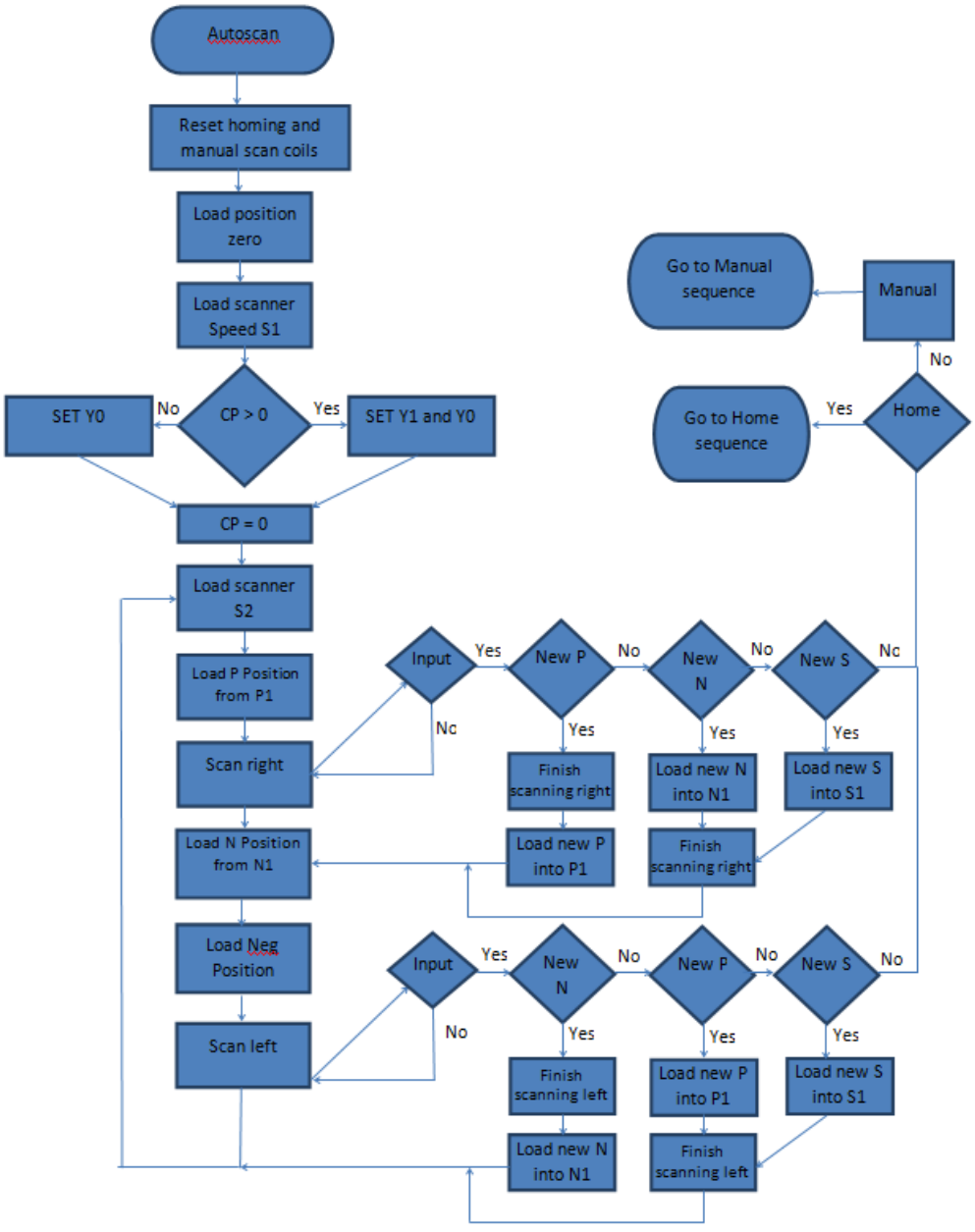

Figure 12. A Flow chart showing the autoscanning sequence of operations

The manual scan function is simply designed to set the scan to move in either positive or negative position until the user changes the input or a limit switch is activated. A flow chart showing the operation of the manual scanning function is shown in Figure 13.

Figure 13. A Flow chart showing the manual scanning sequence of operations

Power Supply

The power supply converts 120/240 alternating current into DC power. The DC power is used to power the stepper motor drive. The power supply that was selected has adjustable voltage from 24-28V and will provide a total of 7.5A.

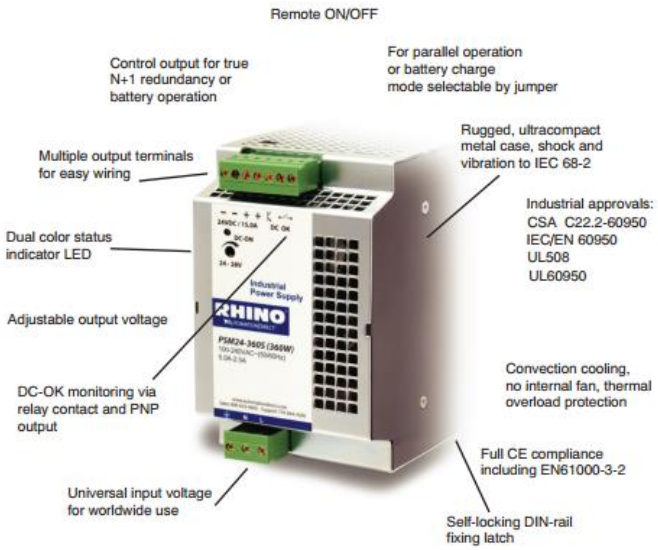
Remote ON/OFF
Control output for true N+1 redundancy or battery operation
For parallel operation or battery charge mode selectable by jumper
Multiple output terminals for easy wiring
Rugged, ultracompact metal case, shock and vibration to IEC 68-2
Industrial approvals: CSA C22.2-60950 IEC/EN 60950 UL508 UL60950
Dual color status indicator LED
Adjustable output voltage
DC-OK monitoring via relay contact and PNP output
Convection cooling, no internal fan, thermal overload protection
Full CE compliance including EN61000-3-2
Universal input voltage for worldwide use
Self-locking DIN-rail fixing latch

Figure 14. A 7.5 amp DC power supply [12]

Stepper Driver

The stepper driver converts the clock pulses and sequences power to the stepper motor windings. The rate of change of current through the windings is crucial for the stepper motor to run at optimal speed and torque. The MBC05641 shown in Figure 15 takes 24-48 volts and provides adjustable current to the stepper motor[13]. The steps per revolution can also be adjusted from 200 steps to 12800 microsteps. The adjustable steps pre revolution is not a feature that will likely be used in the thickness scanner application. The adjustable current allows the drive to be used for different size stepper motors and different wiring configurations of the stepper motors.

Figure 15. The MBC05641 stepper drive takes 24-48V, and provides adjustable current from .5 to 5A and adjustable steps using DIP switches [13].

Stepper Motor

The stepper motor is an electromechanical device that converts electrical pulses into steps. The stepper motor moves a fixed angular increment or step for every electrical pulse. The stepper motors are designed for an angular increment of .9 degrees and 1.8 degrees, 400 and 200 steps per revolution respectively. Stepper motor systems lack feedback to maintain control of position which makes it an open-loop system. However, in this application a proximity sensor will be located on each side of the linear actuator and one will be located in the center. These sensors will act as limit switches for the end of the actuator and a homing sensor for the center of the actuator.

Linear Actuator

The linear actuator is responsible for creating linear motion or converting the rotational motion of the motor into the linear motion required for moving back and forth across the web. There are three main types of linear actuators one of them converts electrical energy directly into linear motion, the other two types use either a belt drive or ball screw drive to convert the rotational motion of a motor. The important aspect of the linear actuator for this application is

the overall stroke of the linear actuator and the distance per revolution. The overall stroke length will have to be larger than 30 inches to accommodate the largest width web and the distance per revolution required is greater than a ½”/revolution. With these requirements a belt driven linear actuator is the most attractive option.

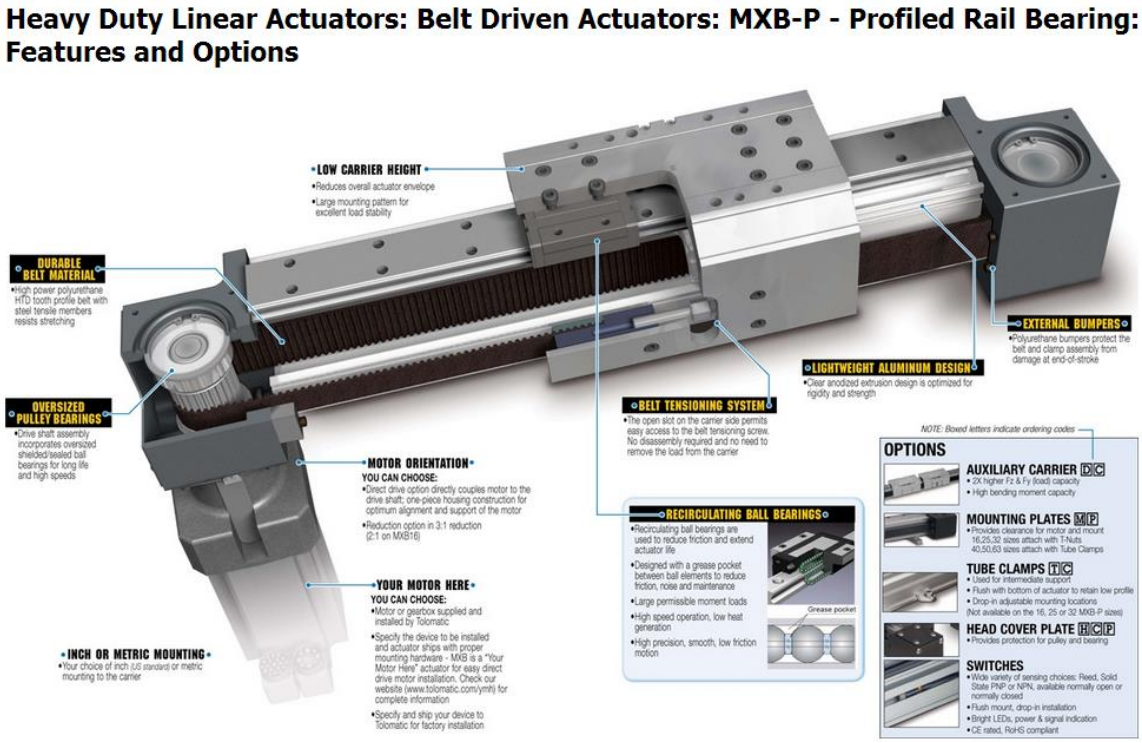
Heavy Duty Linear Actuators: Belt Driven Actuators: MXB-P - Profiled Rail Bearing: Features and Options
LOW CARRIER HEIGHT
Reduces overall actuator envelope
Large mounting pattern for excellent load stability
DURABLE BELT MATERIAL
High power polyurethane HTD tooth profile belt with steel tensile members resists stretching
OVERSIZED PULLEY BEARINGS
Drive shaft assembly incorporates oversized shielded/sealed ball bearings for long life and high speeds
MOTOR ORIENTATION
YOU CAN CHOOSE:
Direct drive option directly couples motor to the drive shaft; one-piece housing construction for optimum alignment and support of the motor
Reduction option in 3:1 reduction (2:1 on MXB16)
YOUR MOTOR HERE
YOU CAN CHOOSE:
Motor or gearbox supplied and installed by Tolomatic
Specify the device to be installed and actuator ships with proper mounting hardware - MXB is a "Your Motor Here" actuator for easy direct drive motor installation. Check our website (www.tolomatic.com/ymh) for complete information
Specify and ship your device to Tolomatic for factory installation
INCH OR METRIC MOUNTING
Your choice of inch (US standard) or metric mounting to the carrier
BELT TENSIONING SYSTEM
The open slot on the carrier side permits easy access to the belt tensioning screw. No disassembly required and no need to remove the load from the carrier
RECIRCULATING BALL BEARINGS
Recirculating ball bearings are used to reduce friction and extend actuator life
Designed with a grease pocket between ball elements to reduce friction, noise and maintenance
Large permissible moment loads
High speed operation, low heat generation
High precision, smooth, low friction motion
Grease pocket
LIGHTWEIGHT ALUMINUM DESIGN
Clear anodized extrusion design is optimized for rigidity and strength
EXTERNAL BUMPERS
Polyurethane bumpers protect the belt and clamp assembly from damage at end-of-stroke
NOTE: Boxed letters indicate ordering codes
OPTIONS
AUXILIARY CARRIER DC
2X higher Fz & Fy (load) capacity
High bending moment capacity
MOUNTING PLATES MP
Provides clearance for motor and mount
16,25,32 sizes attach with T-Nuts
40,50,63 sizes attach with Tube Clamps
TUBE CLAMPS TC
Used for intermediate support
Flush with bottom of actuator to retain low profile
Drop-in adjustable mounting locations
(Not available on the 16, 25 or 32 MXB-P sizes)
HEAD COVER PLATE HCP
Provides protection for pulley and bearing
SWITCHES
Wide variety of sensing choices: Reed, Solid State PNP or NPN, available normally open or normally closed
Flush mount, drop-in installation
Bright LEDs, power & signal indication
CE rated, RoHS compliant

Figure 16. Example of a belt driven linear actuator from Tolomatic [14]

Proximity Sensors

With the motor for the motion sensor having no position feedback there should be limit switches on each side of the linear actuator to stop the machine from damaging itself. The registration profile type also requires a sensor/switch to that triggers the motion profile to change from velocity control to position control. A magnetic induction sensor has been chosen for all three locations. The sensors chosen were model AM1-AN-2H, these sensors are NPN normally open output magnetic induction sensors with a 4mm sensing distance.

3.3 Thickness Measurement system

Using the existing thickness measurement system was made a requirement of this project. The existing non-scanning thickness measurement system is used for measuring specific spots of the web and the probe is moved by hand to examine different areas. The existing measurement system consists of the Permascope benchtop unit, a probe, and a steel back plate. The new measurement system will have one additional component. A serial device server will be used allowing the thickness gauge to be connected to the SCADA PC through Ethernet. The following sections provide a brief overview of the system with the focus on establishing the communication channel through a Moxa Nport 5110 a serial device server.

Fischerscope MMS Permascope benchtop unit

The Permascope module is versatile and can be configured to use either magnetic induction probes or eddy current probes. The magnetic induction probes are used to measure non-magnetic coatings on ferromagnetic substrates such as paint, plastic, or enamel on steel. In this application the magnetic induction probe measures the distance between the probe tip and a steel plate. The probe rides on top of the extruded plastic sheet which separates the probe tip from the steel back plate. The Fischerscope MMS bench top unit can be seen in Figure 17. The Fischerscope has serial communication capability with an RS232 port that can output data. In continuous operation mode the Fischerscope will continually output single measurement readings, the maximum output speed is five measurements per second when the output is configured for single readings with no separator.

Figure 17. Image of a Fischerscope MMS bench top unit[15].

EGA1.3 Magnetic Induction Sensor

The EGA1.3 probe was selected for the thickness scanning system due to the simple integration of the probe into our probe holder and the desired measurement range of the probe. The EGA1.3 has a measurement range of 0 to 60 mils. This probe provides a small measurement range with the highest precision and a high accuracy. A second probe the EGA06H may be investigated which would provide a smaller measurement range, higher accuracy, but a lower precision than the EGA1.3. Table 4 shows the measurement range, accuracy, and precision of the two probes.

Note regarding probe designations: L: cable length for magnetic induction probes 5 m and for eddy current probes 3 m instead of 1.5 m. F: Measuring element protected against moist, aggressive media. T: Intermittent measurements on specimens with temperatures up to 100 °C (212 °F) possible. * Note: Probe capability (accuracy and precision) tested under controlled conditions.	**Description** **Order Number**	**Measurement accuracy*** u_s	Measurement point **Ø for 10% error min. Ø**
	Measurement range	***Measurement precision**** ***s***	***Ø for 10% error min. Ø***
	EGA1.3 602-118	0-50 µm : 0.25 µm 50-1000 µm : 0.5 % 1000-1500 µm : < 2.5 %	ø : 14 mm (550 mils) min. ø : 2 mm (80 mils)
	0-1500 µm *0-60 mils*	*0-50 µm : 0.1 µm* *50-1500 µm : 0.2 %*	*ø : 36 mm (1.4")* *min. ø : 10 mm (400 mils)*
	EGA06H 602-936 EGA06H-L 602-626	0-50 µm : 0.3 µm 50-700 µm : < 2 %	ø : 18 mm (720 mils) min. ø : 1 mm (40 mils)
	0-700 µm *0-28 mils*	*0-50 µm : 0.1 µm* *50-700 µm : < 0.3 %*	*ø : 30 mm (1.2")* *min. ø : 20 mm (800 mils)*

Table 4. Two probes from the Helmut Fischer Probe Catalog [16]

Moxa Nport 5110 RS-232 to TCP/IP server

The Moxa Nport 5110 RS-232 to TCP/IP server is a serial device server that makes networking serial devices easy. A diagram of the Nport 5110 can be seen in Figure 18, the device is small and simple with a single male DB-9 port and a single RJ-45 port. The serial device server has multiple operating modes that can be used to establish communications between a wide variety of serial devices.

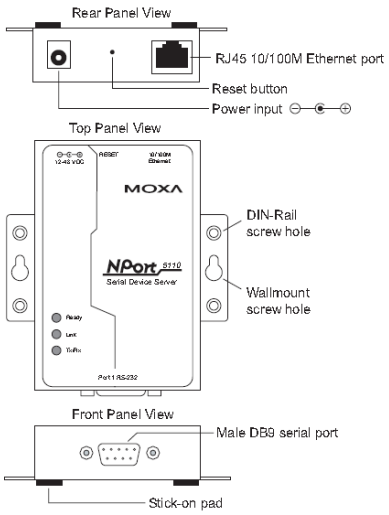

Figure 18. A diagram showing the features of the NPort 5100 series [17]

The device server can be configured using a web based configuration or with the Nport Administrator progam. For this project the Nport Administrator was used to configure the serial device server for communication with the Fischerscope MMS. In order to configure the device server the IP address needs to be set with a proper IP address for the network that it will operating in. In this project the network consists of a single PC and the serial device server. The IP configuration of the PC can be seen in Figure 19, this was determined by issuing the command “ipconfig /all” in the windows command window.

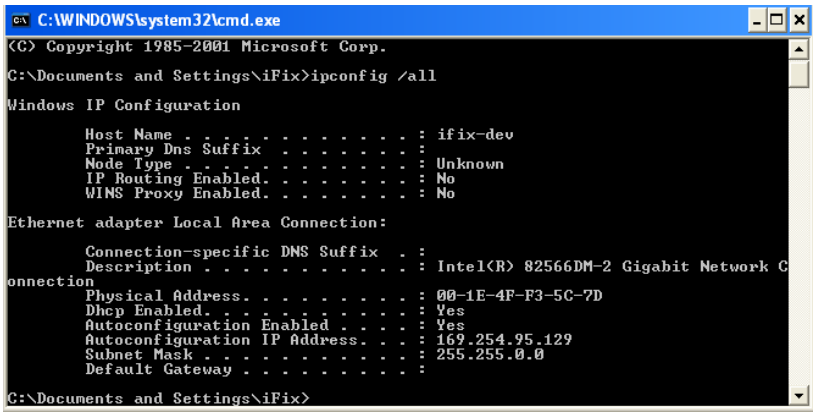
C:\WINDOWS\system32\cmd.exe
(C) Copyright 1985-2001 Microsoft Corp.
C:\Documents and Settings\iFix>ipconfig /all
Windows IP Configuration
Host Name . . . . . : ifix-dev
Primary Dns Suffix . . . . . :
Node Type . . . . . : Unknown
IP Routing Enabled. . . . . : No
WINS Proxy Enabled. . . . . : No
Ethernet adapter Local Area Connection:
Connection-specific DNS Suffix . :
Description . . . . . : Intel(R) 82566DM-2 Gigabit Network C
onnection
Physical Address. . . . . : 00-1E-4F-F3-5C-7D
Dhcp Enabled. . . . . : Yes
Autoconfiguration Enabled . . . . : Yes
Autoconfiguration IP Address. . . : 169.254.95.129
Subnet Mask . . . . . : 255.255.0.0
Default Gateway . . . . . :
C:\Documents and Settings\iFix>

Figure 19. IP configuration of the SCADA PC

The main Nport Administrator window can be seen in Figure 20. The Nports that are connected to the network are displayed in a list in the main window. The bottom window

shows a message log with a date and time stamp. The different functions are accessed through the system tree in the left hand window.

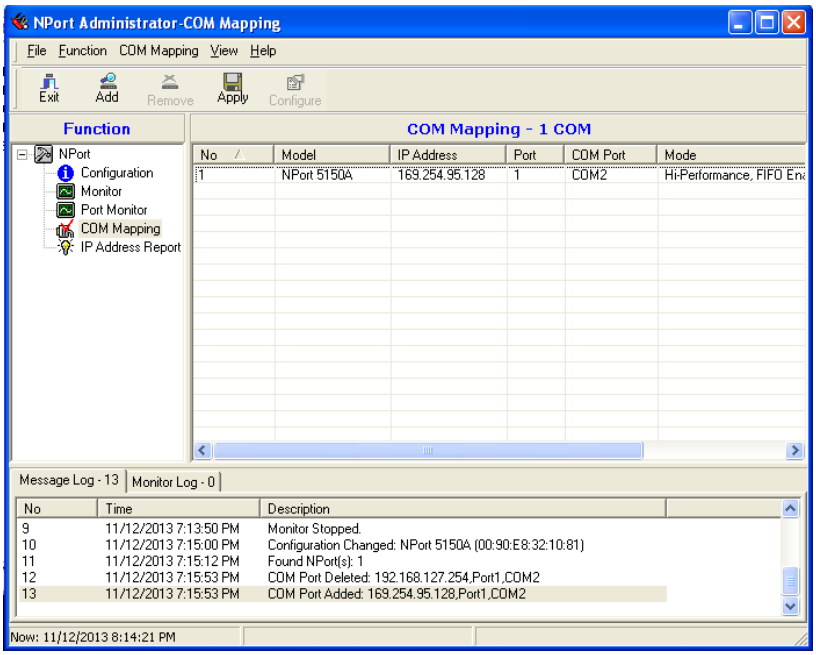
NPort Administrator-COM Mapping
File Function COM Mapping View Help
Exit Add Remove Apply Configure
Function
COM Mapping - 1 COM
NPort
Configuration
Monitor
Port Monitor
COM Mapping
IP Address Report
No Model IP Address Port COM Port Mode
1 NPort 5150A 169.254.95.128 1 COM2 Hi-Performance, FIFO En
Message Log - 13
Monitor Log - 0
No Time Description
9 11/12/2013 7:13:50 PM Monitor Stopped.
10 11/12/2013 7:15:00 PM Configuration Changed: NPort 5150A (00:90:E8:32:10:81)
11 11/12/2013 7:15:12 PM Found NPort(s): 1
12 11/12/2013 7:15:53 PM COM Port Deleted: 192.168.127.254,Port1,COM2
13 11/12/2013 7:15:53 PM COM Port Added: 169.254.95.128,Port1,COM2
Now: 11/12/2013 8:14:21 PM

Figure 20. The mainscreen of the Nport Administrator Software

Selecting “Configuration” and then clicking on the row for the Nport that needs to be configured will display the configuration window as seen in Figure 21.

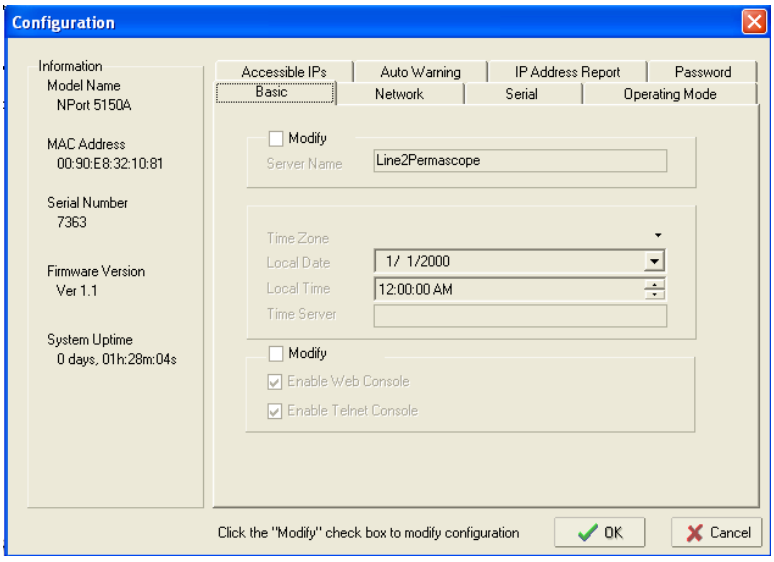

Figure 21. Configuration window from Nport Administrator showing the Basic tab

When configuring the Nport a window with eight tabs opens, in order to configure the Nport for this project only four of these tabs would need to be opened and configured. The four tabs are that needed to be setup are the basic, network, serial, and operating mode. The basic tab allows the server to be named which can be used to easily identify the server when working with many Nports connected to the same network. The network tab which can be seen in Figure 22, is used to configure the network settings. In this case the settings that needed to be set were the IP address and the Netmask.

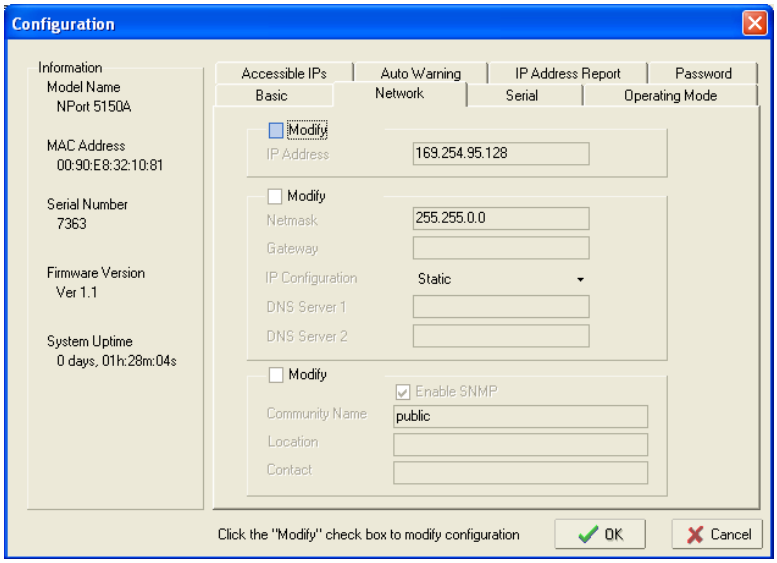

Figure 22. Configuration window from Nport Administrator showing the Network tab

The operation mode that has been used for this application is Real COM mode. Configuring the Nport for Real COM mode is simple with just selecting the mode as in Figure 23. In Real COM mode the Nport serial server acts as a COM port of the host computer and the only setting that needs to be adjusted is the COM port number to be used. The serial settings then need to be configured to match the serial device that is to be connected to the serial server.

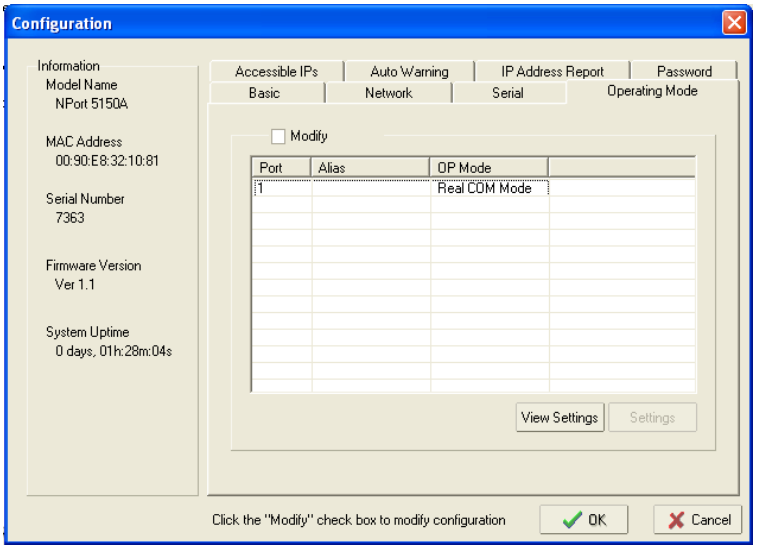

Figure 23. Configuration window from Nport Administrator showing the Operating Mode tab

The serial settings that need to be configured are the Baud Rate, Parity, Data Bits, Stop Bits, Flow Control, FIFO, and interface. These settings all need to match the serial communications settings of the Fischerscope MMS. In figure 24, the serial settings are shown with the baud rate of 9600 the highest baud rate the Fischerscope supports. The other serial settings include, parity set to none, the data bits set to 8, stop bits set to 1, and flow control set to none.

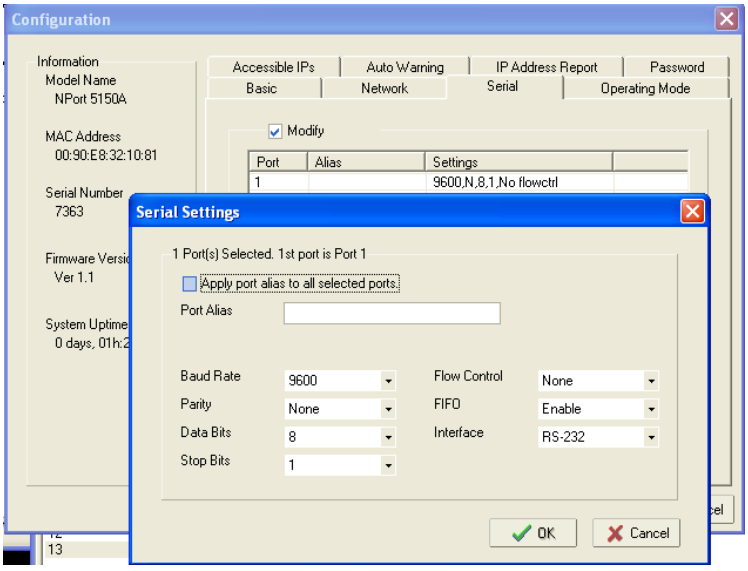

Figure 24. Nport Administrator showing the serial settings

3.4 Supervisory Control and Data Acquisition (SCADA)

Industrial Gateway Server

The Industrial Gateway Server or IGS is an OPC server is used to configure “tags” that can then be added to the process database of iFix, it is responsible for the IO communications of the SCADA. When configuring the IGS the communication channel, device, and then the tags need to be configured. The IGS can have many different communication channels configured, with many devices on each communication channel, and each device having many tags. The main screen of the IGS Administrator can be seen in Figure 25. The left window shows the channels which can be extended to show the devices in each channel. The right window shows all the tags that are configured for the device that is selected; in this figure the Line2ThicknessScanner device is selected. The remainder of this section will discuss the configuration of the channels, devices, and tags used for this project.

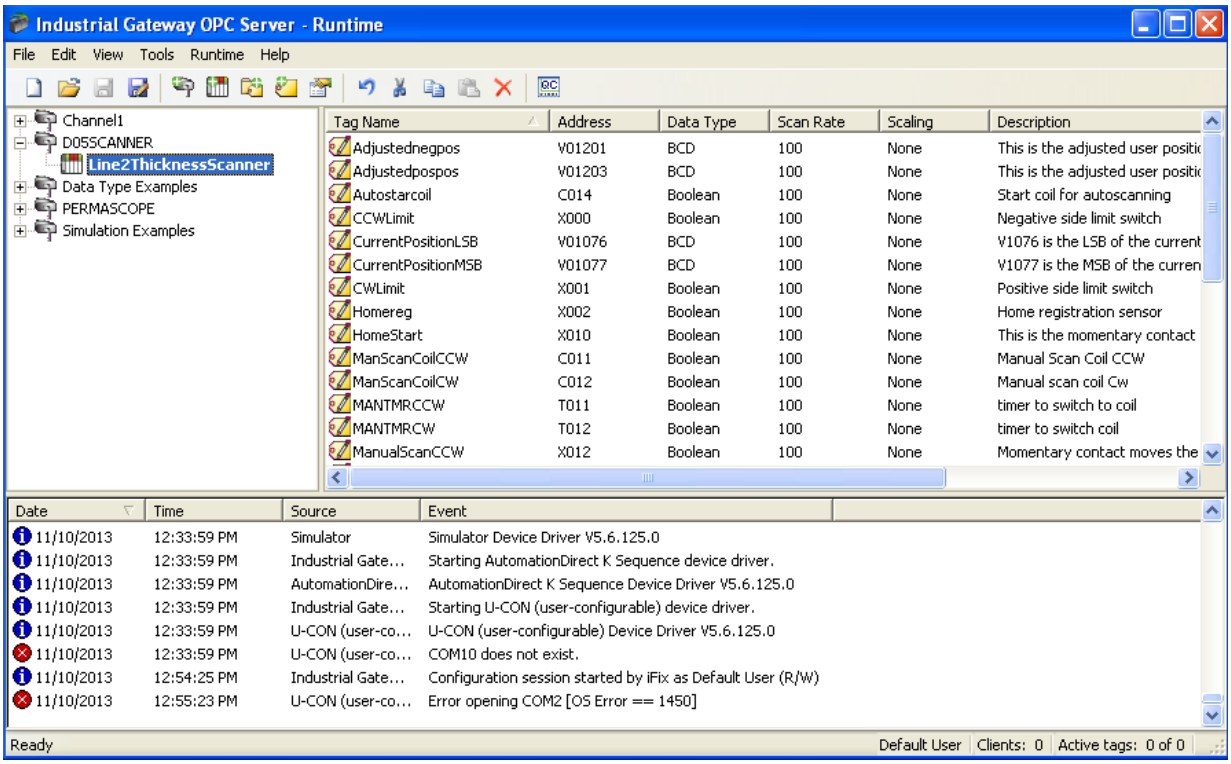
Industrial Gateway OPC Server - Runtime
File Edit View Tools Runtime Help
Channel1
D05SCANNER
Line2ThicknessScanner
Data Type Examples
PERMASCOPE
Simulation Examples
Tag Name | Address | Data Type | Scan Rate | Scaling | Description
Adjustednegpos V01201 BCD 100 None This is the adjusted user positi
Adjustedpospos V01203 BCD 100 None This is the adjusted user positi
Autostarcoil C014 Boolean 100 None Start coil for autoscanning
CCWLimit X000 Boolean 100 None Negative side limit switch
CurrentPositionLSB V01076 BCD 100 None V1076 is the LSB of the current
CurrentPositionMSB V01077 BCD 100 None V1077 is the MSB of the curren
CWLimit X001 Boolean 100 None Positive side limit switch
Homereg X002 Boolean 100 None Home registration sensor
HomeStart X010 Boolean 100 None This is the momentary contact
ManScanCoilCCW C011 Boolean 100 None Manual Scan Coil CCW
ManScanCoilCW C012 Boolean 100 None Manual scan coil Cw
MANTMRCCW T011 Boolean 100 None timer to switch to coil
MANTMRCW T012 Boolean 100 None timer to switch coil
ManualScanCCW X012 Boolean 100 None Momentary contact moves the
Date | Time | Source | Event
11/10/2013 12:33:59 PM Simulator Simulator Device Driver V5.6.125.0
11/10/2013 12:33:59 PM Industrial Gate... Starting AutomationDirect K Sequence device driver.
11/10/2013 12:33:59 PM AutomationDire... AutomationDirect K Sequence Device Driver V5.6.125.0
11/10/2013 12:33:59 PM Industrial Gate... Starting U-CON (user-configurable) device driver.
11/10/2013 12:33:59 PM U-CON (user-co... U-CON (user-configurable) Device Driver V5.6.125.0
11/10/2013 12:33:59 PM U-CON (user-co... COM10 does not exist.
11/10/2013 12:54:25 PM Industrial Gate... Configuration session started by iFix as Default User (R/W)
11/10/2013 12:55:23 PM U-CON (user-co... Error opening COM2 [OS Error == 1450]
Ready
Default User
Clients: 0
Active tags: 0 of 0

Figure 25. The mainscreen of Industrial Gateway OPC Server

The IGS has an enormous list of drivers that can be used for communicating with all different devices. This project uses the AutomationDirect K Sequence driver to communicate with the Koyo direct logic 05 plc. This driver allows tags to be generated for inputs, outputs, coils, and memory registers. The Permascope channel uses the UCON driver which is a user configurable driver used for generic serial communication devices. The driver that is chosen when setting up the channel changes the configuration options available. There are two additional tabs for configuring the UCON driver when compared to the K sequence driver. The channel properties window for each of these channels can be seen in Figure 26.

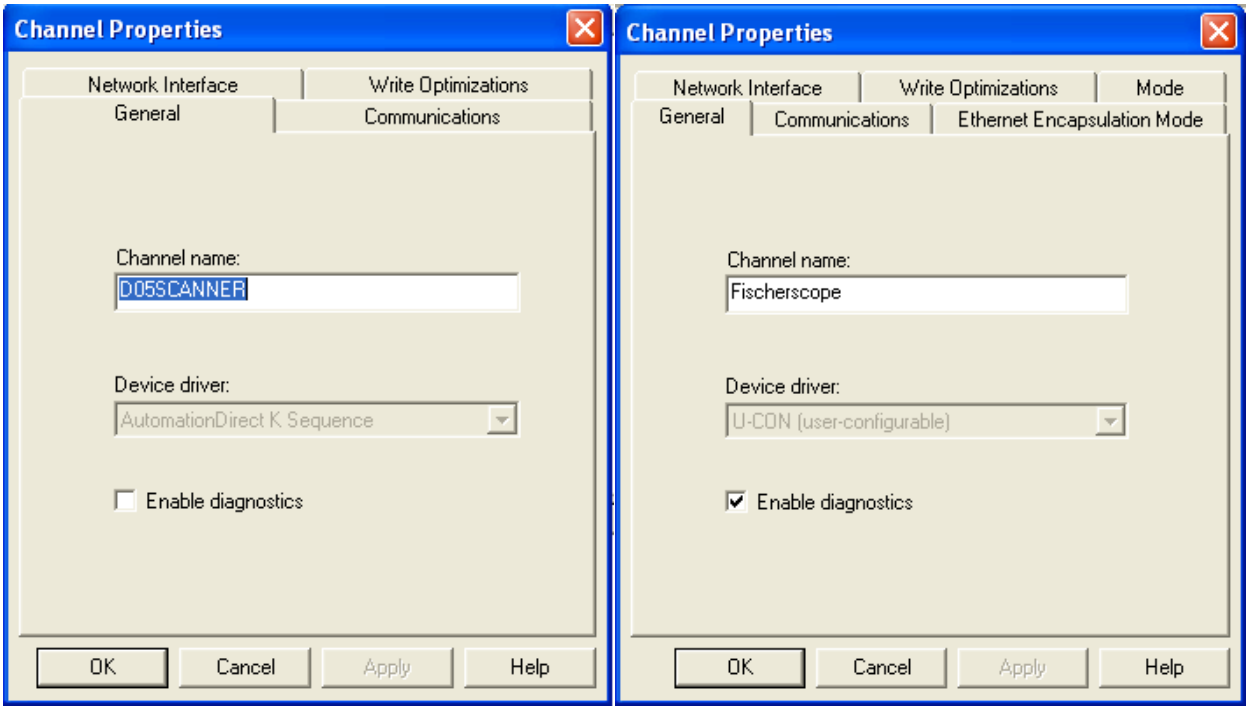

Figure 26. The Channel Properties window for the PLC is shown on the left, the thickness gauge on the right

One important tool for troubleshooting channel communications is to enable the channel diagnostics located under the general tab of the channel properties. After enabling diagnostics has been activated the channel diagnostic can be opened, showing the transmitted and received data. The diagnostics for the D05SCANNER channel is shown in figure 27.

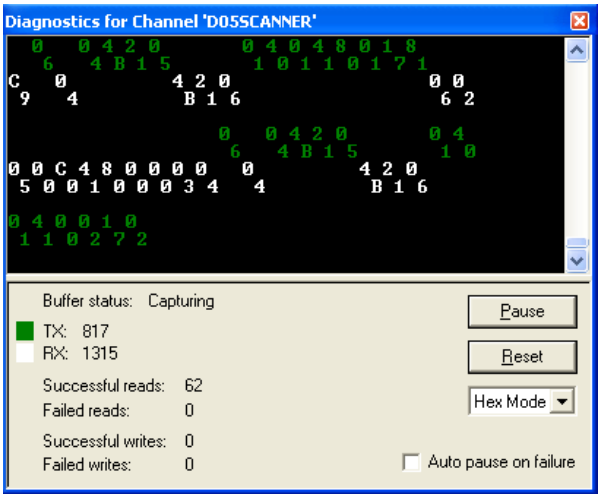

Figure 27. IGS Diagnostics tool showing the channel communications

The IGS channel properties communications tab allows configuration of the serial communications. The connection type, COM ID, baud rate, data bits, parity, stop bits, and flow control can be set on the communications page. Setting up the communication for the thickness gauge these settings need to match the communication settings of the Moxa Nport and the Fischerscope. The Koyo direct logic 05 PLC D0-05DD is going to be connected to an existing COM port on the PC and only requires that the IGS and the PLC have matching communication settings. An example of the IGS serial communication settings can be seen in Figure 28.

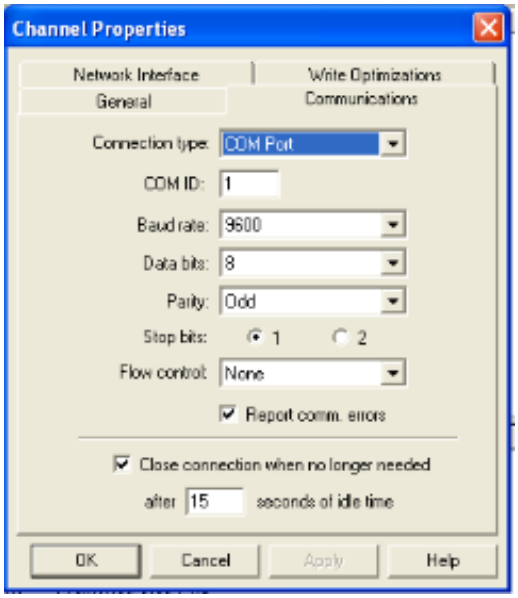

Figure 28. Channel Properties window showing the communications settings for the D05 scanner

In order to achieve the highest data rate from the Fischerscope thickness gauge the IGS has to be configured in unsolicited mode. The Fischerscope will be setup in continuous mode and will output a single reading every 200ms. The channel had to be configured for unsolicited mode when the channel was initially setup. Figure 29 shows the channel properties mode tab and options for unsolicited mode. This will work as a one-way channel were the IGS reads the thickness values without having to issue a command to the Fischerscope.

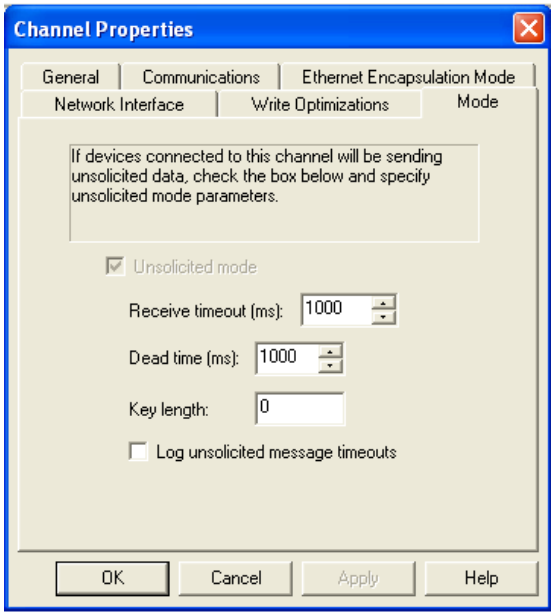

Figure 29. The channel properties mode being set to unsolicited mode

Once the channel settings had been configured devices could be added to the channels. For this project two separate channels have been configured, one for the Fischerscope and one for the PLC. The Fischerscope device is configured for the Permascope channel and the PLC is configured for the D05SCANNER channel. The device properties window is shown in Figure 30, the device properties window has five tabs for configuring the device.

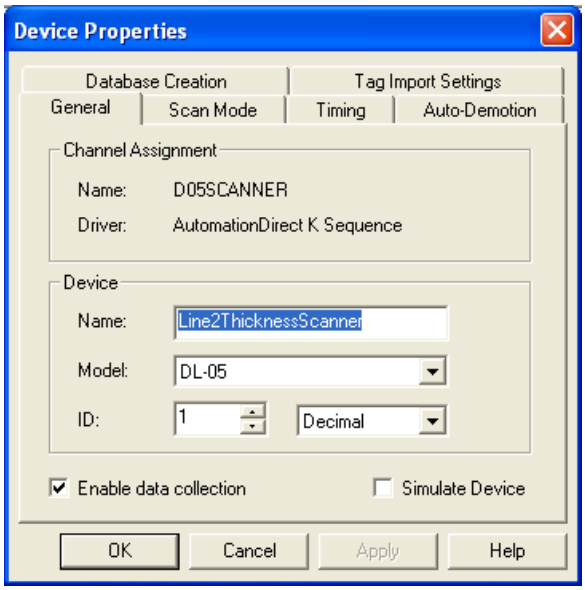

Figure 30. IGS Device properties window showing the general settings tab for the DL05 PLC

The general tab allows the device to be named, the model to be selected, the ID set and type of ID to be selected. The Scan Mode, Timing, and Auto-Demotion tabs are used for configuring how the IGS scans the device to update the tags associated with the device. The Scan Mode can be set to “respect client specified scan rate”, “request data no faster than”, or “request all data at”, descriptions of each mode can be seen in Figure 31. In this project the default option of respect client specified scan rate will be used.

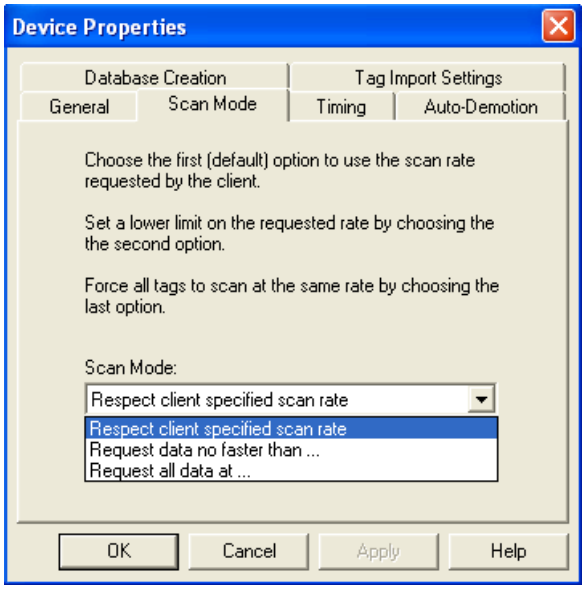
Device Properties
Database Creation
Tag Import Settings
General
Scan Mode
Timing
Auto-Demotion
Choose the first (default) option to use the scan rate requested by the client.
Set a lower limit on the requested rate by choosing the the second option.
Force all tags to scan at the same rate by choosing the last option.
Scan Mode:
Respect client specified scan rate
Respect client specified scan rate
Request data no faster than ...
Request all data at ...
OK
Cancel
Apply
Help

Figure 31. IGS Device properties window showing the different scan modes available

The timing tab shown on the left side of Figure 32, allows the communication request timeout, number of successive timeouts before failure and an inter-request delay to be configured. In serial communications were the device needs time to process and respond; the inter-request delay can be set to account for the processing and response time of the device. The right side of Figure 32 shows the auto-demotion tab, these settings can be used to stop the communications after a number of successful failures and restart communications after a set amount of time. In larger projects were large amounts of data tags are being scanned these options free up resources when communication failures are occurring.

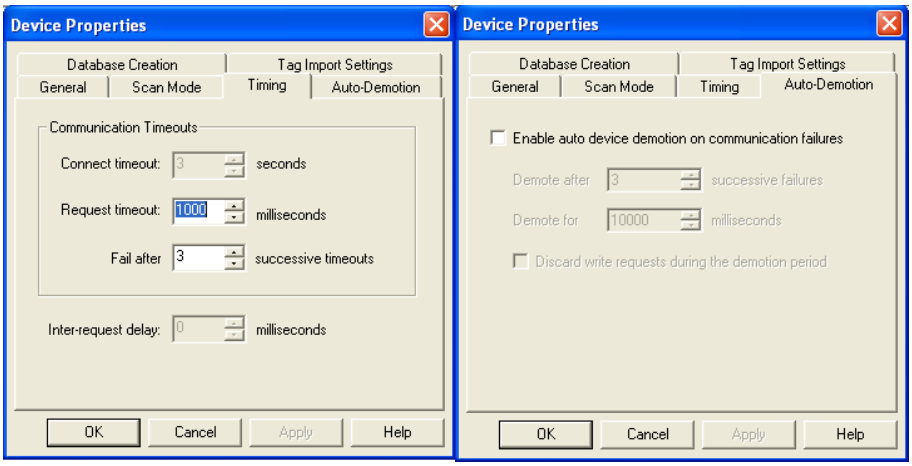

Figure 32. The window on the left shows the Timing tab of the IGS device properties window, the right side shows the Auto-demotion tab of the IGS device properties window.

When using the UCON driver the device properties window has two additional tabs that needed to be configured for this project. The “unsolicited message wait time” can be seen on the left side of figure 33, this setting determines the length of time before setting the _UnsolicitedPcktRcvdOnTime system tag. This tag is a Boolean that is set when the unsolicited message is not received within the time set. The transaction editor tabs main purpose is to launch the transaction editor, the tab also allows password protection to be setup. The transaction editor tab can be seen on the right side of Figure 33.

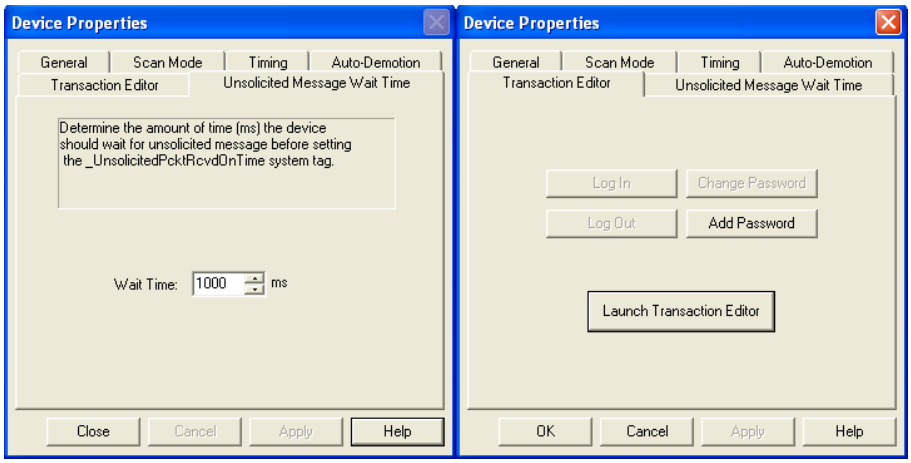

Figure 33. The window on the left shows the Unsolicited Message Wait Time tab of the IGS device properties window, the right side shows the Transaction Editor tab of the IGS device properties window.

The transaction editor can be seen in Figure 34, on the left side the devices and tags can be seen. Below the thickness tag the type of transaction is shown, for this project the type of transaction is “unsolicited”. In the window on the right side of Figure 34 the transaction steps are shown. The first step is a read response step that stops after a specific character is received. The message from the Permascope ends with a carriage return which in Hexadecimal is a D. The read response writes the string into the read buffer until it receives the carriage return which ends the message. The second step the transaction editor performs is updating the tag. This step moves a set length of data stored in the read buffer into the tag, filling blanks with zeros.

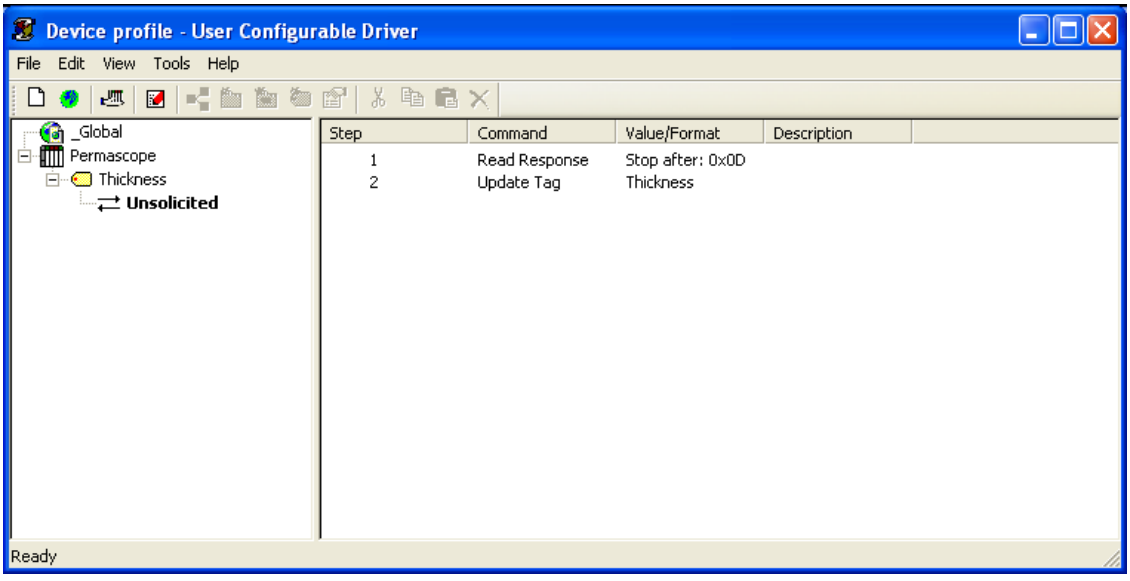

Figure 34. The IGS transaction editor is used to send commands and receive responses, the editor has the capability to parse data and update tags.

The last step in configuring the IGS OPC server is generating the tags associated with each device. The Koyo direct logic 05 PLC will need to have tags associated with any V-memory register, input, or coil that the user will need to interact with. The V-memory registers hold a four digit BCD and need to have their tags configured for this data type. An example of the BCD data type tag and the addressing format can be seen in Figure 35. The client access and the scan rate can also be configured for each tag. The scaling tab allows the raw data from the device to be scaled, however in this project all of the scaling is performed in the process database.

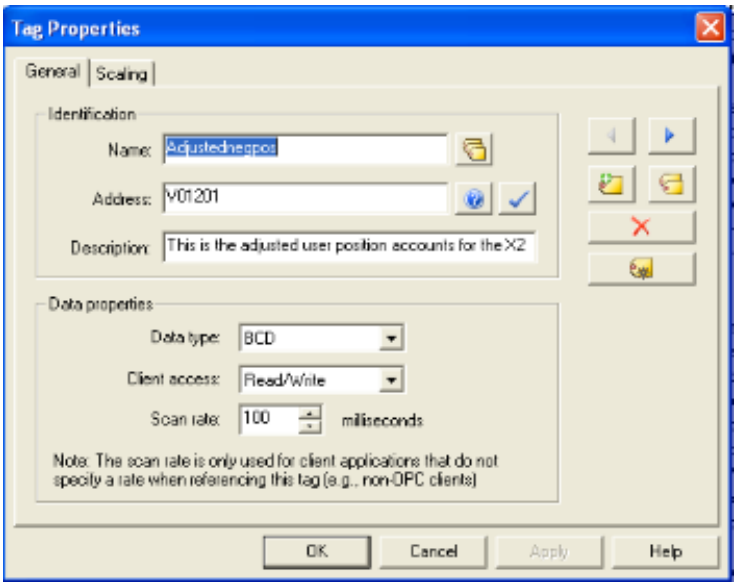

Figure 35. The tag properties window for a tag setup with a BCD data type, shows the PLC V-memory address, description, and scan rate

The inputs and coils use on/off signals and are configured as a Boolean data type. On the left side of Figure 36 the Start Scanning tag is shown as an example of a Boolean logic configuration. The X address is an input type address which can hold a 1 or a 0 representing the on/off conditions. The Permascope only requires a single tag for the thickness data. The right side of Figure 36 shows the configuration of the Thickness tag as an ASCII string data type with a fixed data length of 7 characters.

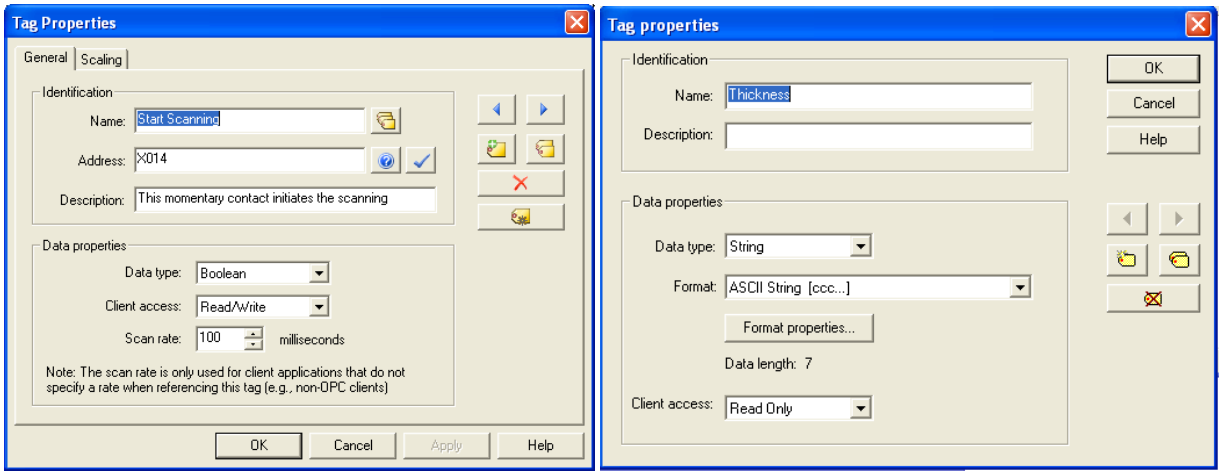

Figure 36. The left side of the figure shows the tag properties of a boolean data type tag from the PLC, the right side shows the tag properties of a string date type tag from the thickness gauge

Process Database

The process database is a major component of the SCADA which organizes process data into individual units of information. These units of information are called “tags.” The tags can interact with the OPC server reading and writing data to the control hardware. The process database can also manipulate the data for calculations, secondary functions and internal logic. The system configuration utility (SCU), shown in Figure 37, is used to configure the SCADA node and the process database settings. The monitor shows the current NODE, PDB, and the iFix version. On the left of the monitor the drivers that have been configured for the system are shown, in this case the IGS and SM2 drivers have been configured. The icon ribbon at the bottom of the screen is used to setup the Path Configuration, Alarm Configuration, Network Configuration, SCADA Configuration, Task Configuration, Security Configuration, SQL Configuration, and Alarm Area Configuration. In this project most of the settings used are the default settings and did not require modification.

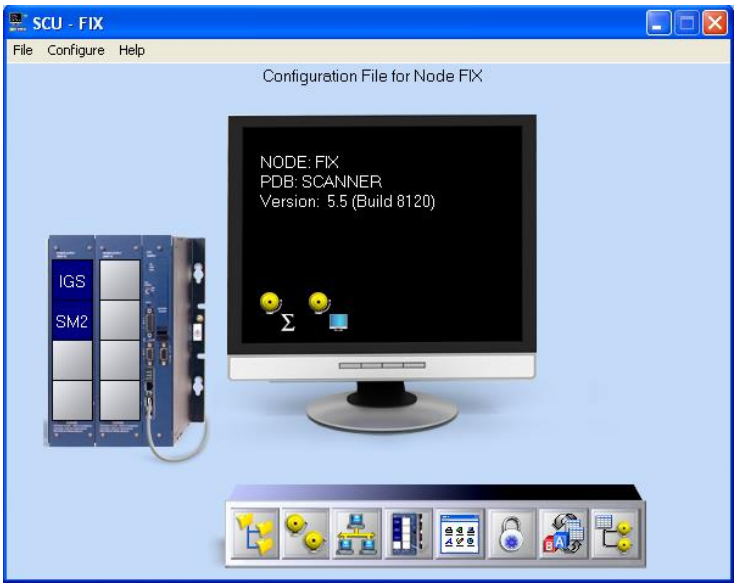

Figure 37. The main screen for the system configuration utility

Once the SCU was configured the process database (PDB) could be opened and tags could be added to the database as needed. Initially the tags that had been added to the IGS were added to the PDB. However, the process database and the human machine interface (HMI) were developed concurrently with tags being added to the PDB as they were needed for the HMI. The PDB has a large variety of tags that can be used to read/write data and manipulate the data, Figure 38 shows all the tags available in iFix version 5.5. The remainder of this section will discuss the different tags used in this project and how they were configured. The tags belong to one of three categories, primary blocks, secondary blocks, or batch blocks. Primary blocks are essentially tags that have the ability to read from or write to a Driver Image Table (DIT). These tags can be stand-alone blocks or can be linked to other blocks in tag chains.

Typical primary tags are the Analog Input and Digital Input tags.

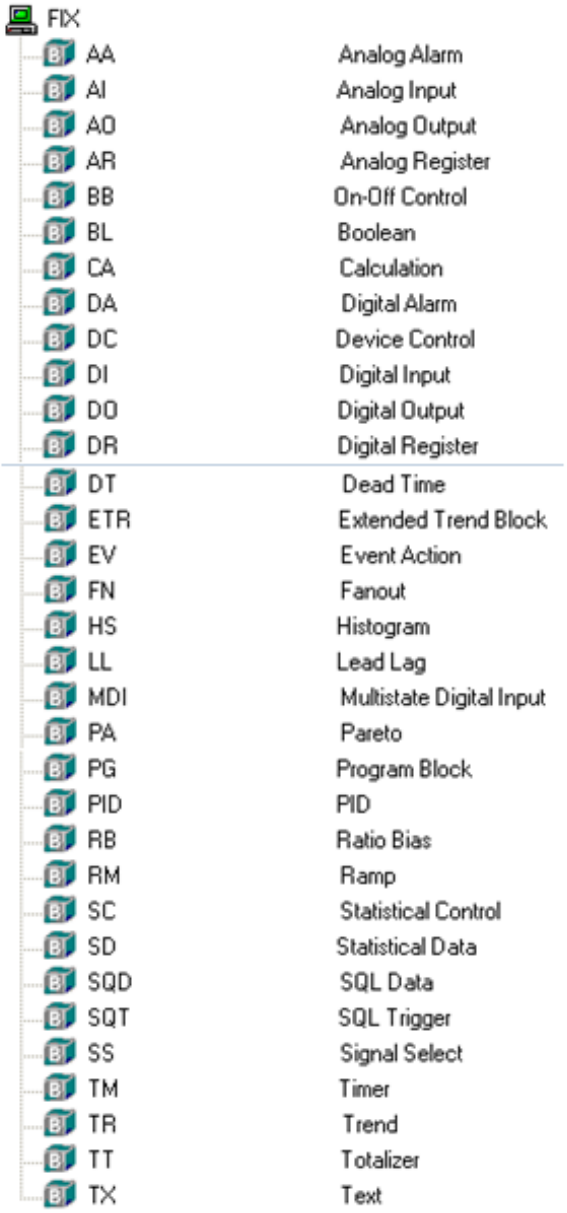

Figure 38. This list shows all the types of tags (blocks) available in the iFix 5.5 process database

The secondary blocks receive and send data to and from other tags, not from the Driver Image Table. These tags cannot be stand-alone tags and have to be part of a chain that starts with a primary tag. Secondary tags typically perform calculations and logic with data retrieved from a primary block. The program block is not a primary block or secondary block, these are special blocks known as batch blocks. These blocks are stand-alone blocks that can execute

simple 20 line programs to help with internal database actions and logic, allowing additional automation options for various processes.

The number of tags coming from the IGS driver is rather small compared to the total number of tags in the system which can be seen in Figure 39. There are 26 tags using the IGS driver out of a total of 668 tags in the PDB. All of the IGS tags are primary tags that are either Digital Inputs or Analog Inputs depending on whether the data is Boolean or BCD. The digital tags are used to turn components or functions on or off. The analog tags are used to set or report on the scanning positions and speed of the system, as well as report the thickness value. The fifth column of the process database shows the scan times of the PDB blocks.

643	AUTOSTARTCOIL	DI	The starting coil for autoscanning	1	IGS	D05SCANNER.Line2Thicknes	OPEN	ON
644	CCWLIMIT	DI	negative side limit sensor	1	IGS	D05SCANNER.Line2Thicknes	OPEN	ON
645	CURRENTPOS	AI	This tag is the current position of the	1	IGS	D05SCANNER.Line2Thicknes	4.5	ON
646	CURRENTPOSRAW	AI	The raw pulse current position	0.05	IGS	D05SCANNER.Line2Thicknes	2,325	ON
647	CURRENTPOSMSB	AI	used to determine direction	1	IGS	D05SCANNER.Line2Thicknes	1	ON
648	CWLIMIT	DI	positive side limit sensor	1	IGS	D05SCANNER.Line2Thicknes	OPEN	ON
649	GAGEFACTOR	AI		1	IGS	D05SCANNER.Line2THicknes	0.97	ON
650	HOMECOIL	DI	The starting coil for autoscanning	1	IGS	D05SCANNER.Line2Thicknes	OPEN	ON
651	HOMESENSOR	DI	Digital signal for homesensor	1	IGS	D05SCANNER.Line2Thicknes	OPEN	ON
652	HOMESTART	DI	starts homing function	1	IGS	D05SCANNER.Line2Thicknes	OPEN	ON
653	MANSCOILCCW	DI	Manual Scan coil CCW	1	IGS	D05SCANNER.Line2Thicknes	OPEN	ON
654	MANSCOILCW	DI	Manual Scan Coil CW	1	IGS	D05SCANNER.Line2Thicknes	OPEN	ON
655	MANTMRCCW	DI	timer for manual ccw coil	1	IGS	D05SCANNER.Line2Thicknes	OPEN	ON
656	MANTMRCW	DI	timer for manual cw coil	1	IGS	D05SCANNER.Line2Thicknes	OPEN	ON
657	MANUALSCANCCW	DI	Sets manual scan towards negative	1	IGS	D05SCANNER.Line2Thicknes	OPEN	ON
658	MANUALSCANCW	DI	Sets manual scan towards positive	1	IGS	D05SCANNER.Line2Thicknes	OPEN	ON
659	NEGATIVESCOIL	DI	Negative direction autoscan coil	1	IGS	D05SCANNER.Line2Thicknes	OPEN	ON
660	POSITIVESCOIL	DI	Positive autoscan coil	1	IGS	D05SCANNER.Line2Thicknes	OPEN	ON
661	AUTOSTART	DI	starts autoscanning function	1	IGS	D05SCANNER.Line2Thicknes	OPEN	ON
662	STOP	DI	Stops all scanner motion	1	IGS	D05SCANNER.Line2Thicknes	OPEN	ON
663	CURRENTVELOCITY	AI	Contains the profile type and velocit	1	IGS	D05SCANNER.Line2Thicknes	9,023.00	ON
664	TARGETVELOCITY	AI	target velocity stored in the profile	1	IGS	D05SCANNER.Line2Thicknes	9,023	ON
665	NEGATIVEPOS	AI	User entered positive position	1	IGS	D05SCANNER.Line2Thicknes	-5.4	ON
666	POSITIVEPOS	AI	User entered positive position	1	IGS	D05SCANNER.Line2Thicknes	4.6	ON
667	AUTOVELOCITY	AI	Sets the speed for the autoscan fun	1	IGS	D05SCANNER.Line2Thicknes	0.4	ON
668	THICKNESSRAW	AI		0.20	IGS	Fischerscope.Permascope.Th	1.99	ON

Figure 39. A screen shot of the process database showing all the tags associated with the IGS

The THICKNESSRAW is being collected at its maximum rate of 200 milliseconds, the CURRENTPOSRAW is being collected at a speed of 5 milliseconds. The remaining IGS tags are being scanned at the default setting of 1 second. Figure 40 shows the basic configuration of the THICKNESSRAW tag. The THICKNESSRAW tag is an analog input primary tag which begins a tag chain that is used for displaying the current thickness value. The driver, I/O address, scan time, and engineering units are configured on the basic configuration tab. The “Next” input is also

configured on this tab, which shows that the next tag in the tag chain is the THICKNESSFACTORED tag.

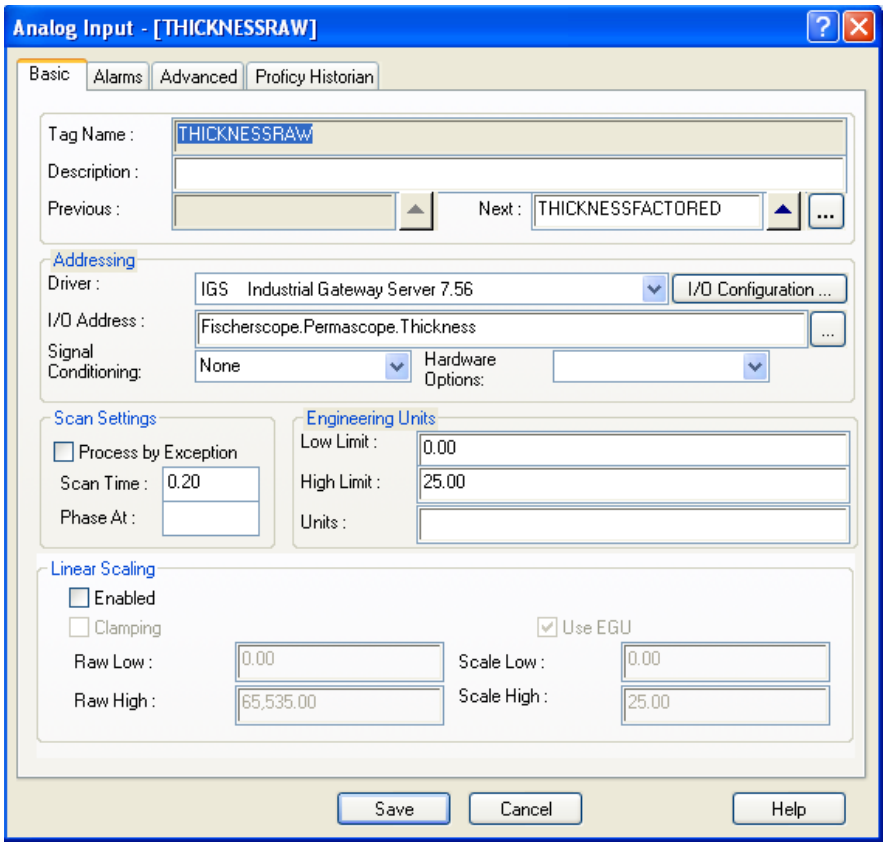

Figure 40. The tag configuration window for an analog input type tag being generated in the process database

The THICKNESSFACTORED tag is a simple calculation tag which multiplies the THICKNESSRAW tag with the GAGEFACTOR tag. The GAGEFACTOR tag is a primary tag that allows the user to input a value from 0 to 2 and acts as a correction factor for the thickness value. The basic configuration of the THICKNESSFACTORED calculation tag can be seen in Figure 41. Calculation tags can have up to eight values that are used in the calculation. If more than eight values are needed for the calculation the calculation tags can be chained together with the output of one calculation tag feeding into the next calculation tag. The values in these blocks can be constants or can be values from other tags, the letters associated with the values can then be used in the Output Calculation line.

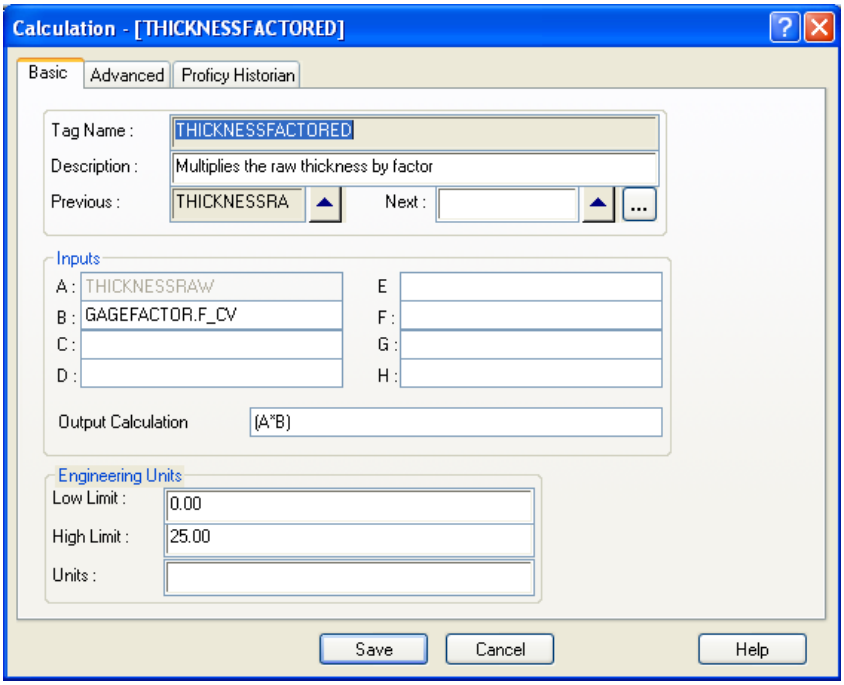

Figure 41.The tag configuration window for a calculation type tag being generated in the process database

The AUTOSTART tag is a primary digital input tag which begins a tag chain used to start the auto-scanning function. The configuration screen for the AUTOSTART digital input can be seen in Figure 42. The tag name, addressing, scan settings and labels can be configured.

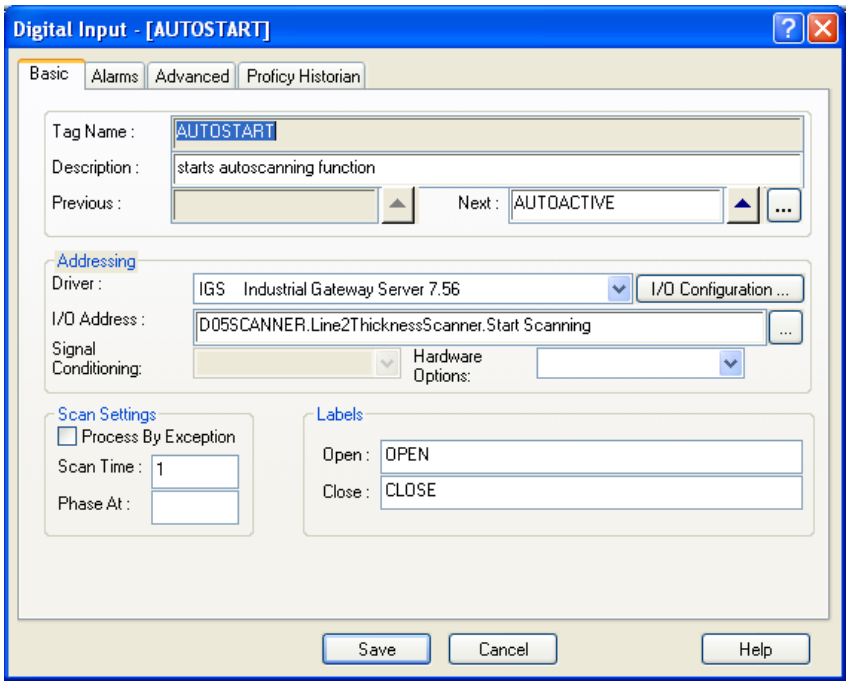

Figure 42. The tag configuration window for an digital input type tag being generated in the process database

The default settings for the labels are open and close but these can be customized for the application for instance to start and stop. The open state corresponds to a zero and the closed state corresponds to a one. The scan time can be adjusted however the default setting of one second is sufficient for the digital tag. The next tag in the AUTOSTART chain is a Boolean tag called AUTOACTIVE. The AUTOACTIVE tag takes inputs from the digital input tags associated with the auto scanning function to determine if the function is active. The four inputs can be seen in Figure 43, which shows the configuration screen of the AUTOACTIVE Boolean tag. The Boolean tag is similar a calculation tag with eight inputs and an output calculation line. In this case if any of the inputs are closed than the output is closed.

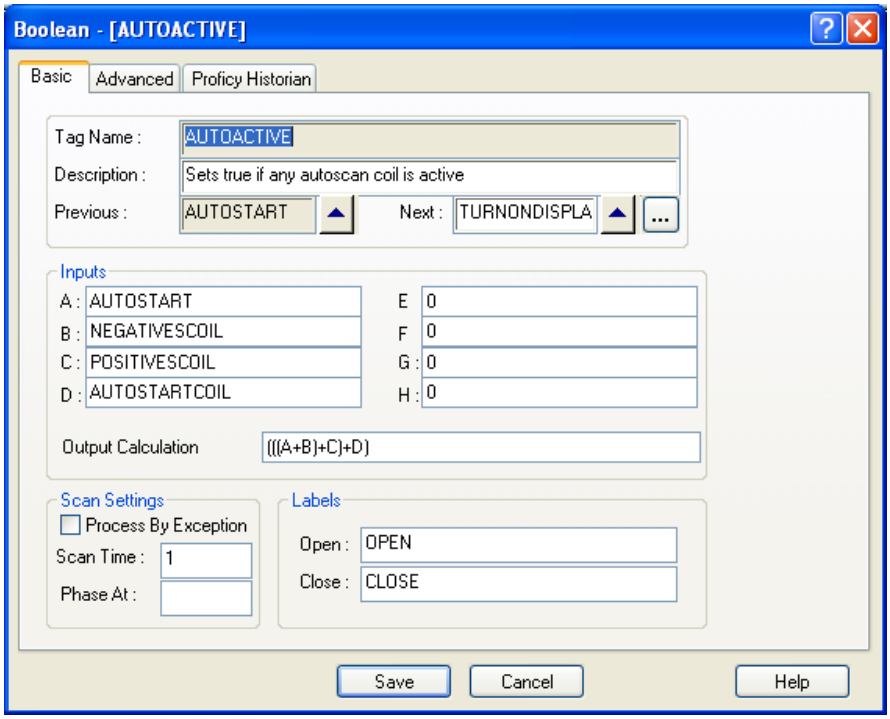

Figure 43. The tag configuration window for an Boolean type tag being generated in the process database

The two primary pieces of data that were needed for this system were the thickness data and the scanner position data. The gathering of the thickness raw data and the factoring of the thickness data was discussed earlier in this section. The “current raw position data” was gathered in a primary analog input tag named CURRENTPOSRAW. In the analog input tag the engineering units were configured based on the number pulses per inch of travel, making the engineering units equal to an inch. The position data then needed to go to more than one tag

so it could be manipulated for different purposes. A FanOut tag named CURRENTPOSITIONOUT was chained with the primary position tag, shown in Figure 44. The FanOut tag allows the data from the original tag to be sent to four different tags. In this case the position data was sent to a tag used for displaying the position, and a tag used for generating the chart.

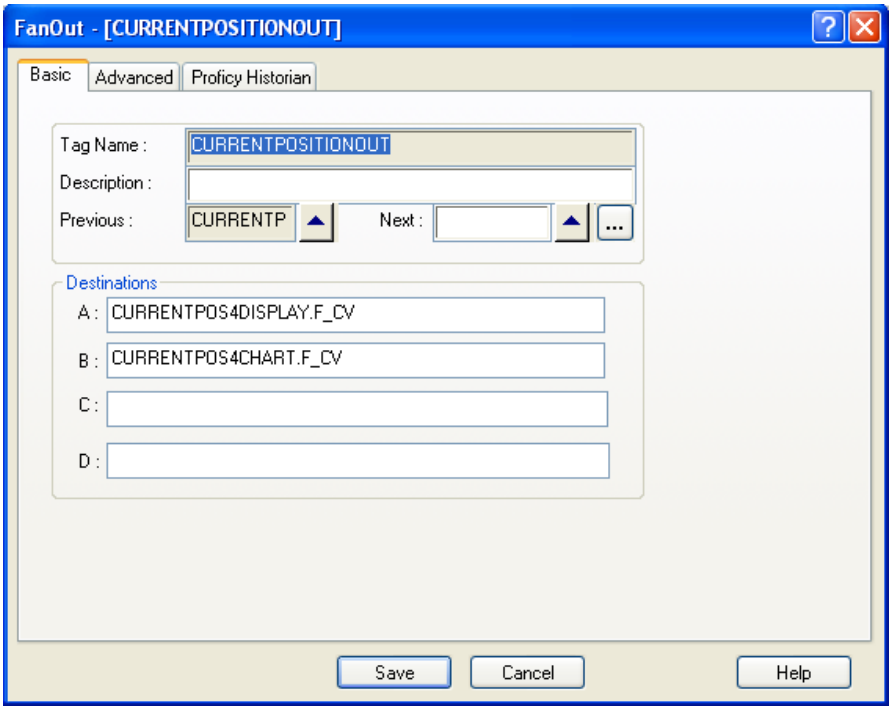

Figure 44. The tag configuration window for an FanOut type tag being generated in the process database

The position data needed to be manipulated due to the how the negative and positive numbers are represented in the PLC. The position data in the PLC is a long BCD with the most significant digit indicating whether or not the number is negative, an eight in this position indicates that the number is negative. In order to display the current position, as negative or positive, a calculation tag was used which can be seen in Figure 45. The calculation tag had three inputs, the CURRENTPOS4CHART, a constant negative one, and CURRENTPOSMSB an analog input tag. The CURRENTPOSMSB scans the most significant bit of the current position and scales the data from one to negative one. The eight which represents a negative number would scale to one and the zero which represents a positive would scale to negative one. Since the first calculation has positive and negative positions reversed, multiplying the result by negative one corrects the orientation of the position data.

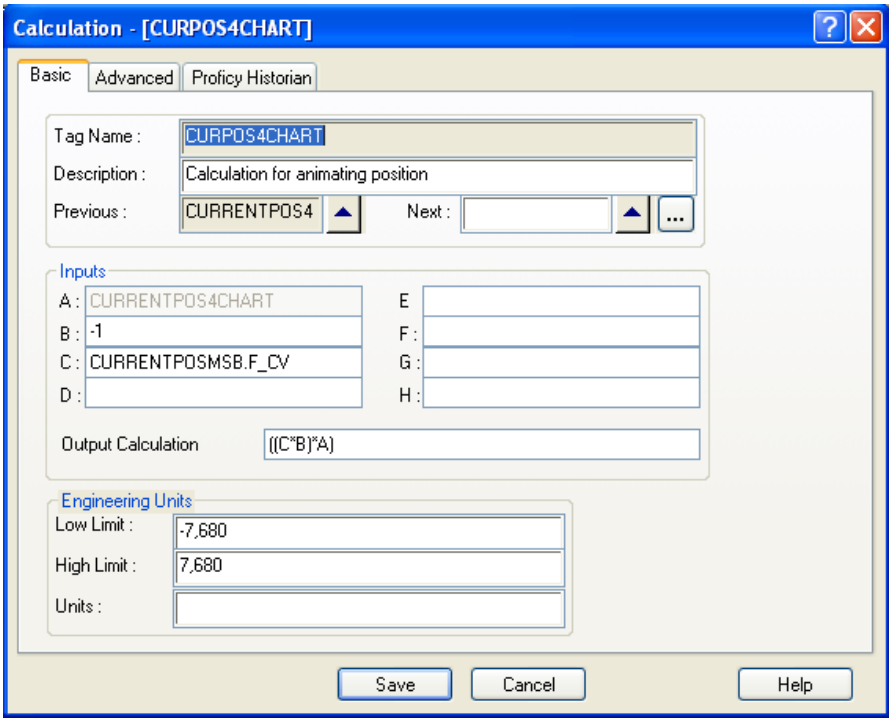

Figure 45. Calculation tag configuration window that shows how the current position for the thickness profile chart is calculated

The engineering units of the CURPOS4CHART tag have a range of -7680 to 7680. The linear actuator moves approximately 3.125 inches per revolution and the stepper drive was configured for microstepping at 1600 pulses per revolution. Dividing the pulses per inch by the inches per revolution gives the number of pulses required to travel one inch, which is 512. The max web width is going to be 30 inches, so the limits have been setup for positive 15 and negative 15 inches.

Once the CURPOS4CHART tag was generated the tag value could be used to identify the position and associate a thickness value to that position. In order to associate the thickness value with a position programming blocks were setup. The programming blocks allow twenty lines of programming to automate different processes. The resolution of the chart impacts the number of programming blocks that are required, it was determined that a quarter inch resolution would be sufficient for this process. With a web that is 30 inches wide the required thickness tags would be 120. The main programming block which is not shown simply determines if the position is a positive or negative value and then activates the appropriate

programming block. The programming blocks shown in Figures 46 and 47 are examples of how the thickness values are associated with a position, when the position is a positive value. The programming blocks start running with line 1 and will continue running command lines in sequence until it reaches the last command or an END statement. In these program blocks the GOTO command is used to skip lines that do not need to run.

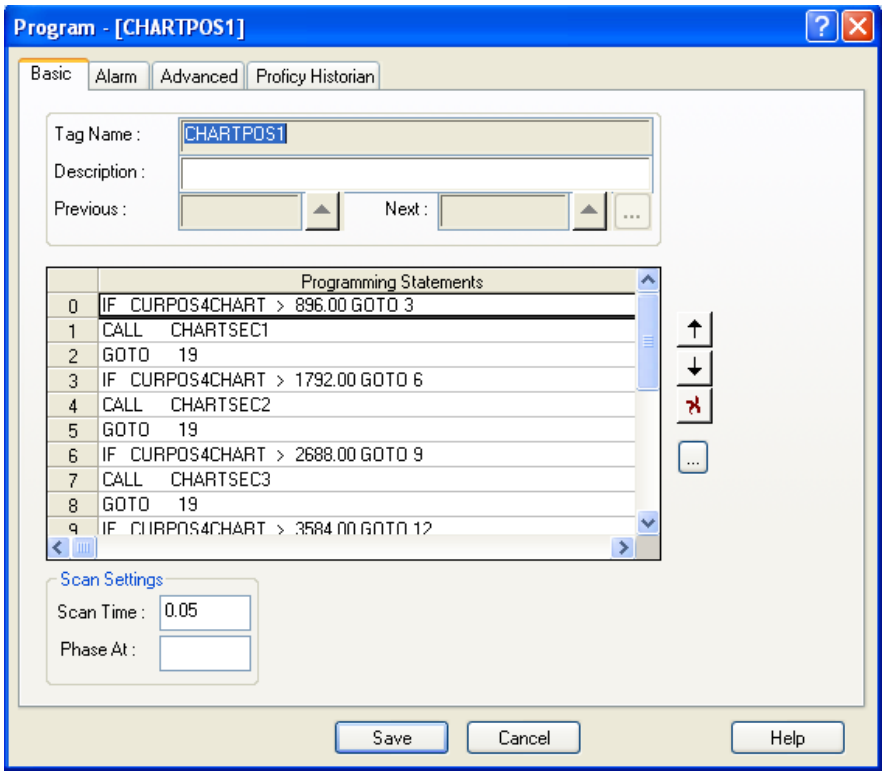

Figure 46. The tag configuration window for a program block being generated in the process database, this program block determines the chart section that the current position falls into and calls the next program block needed.

The CHARTPOS1, shown in Figure 46, is the first positive position programming block that runs when the main programming block calls it. In this block the current position is compared to a constant value that was determined based on the chart resolution and the number of programming lines available in each programming block. Using a current position of positive one inch from the zero point which is equal to 512 pulses for an example, than the CHARTPOS programming block would call the CHARTSEC1 programming block shown in Figure 47. Then the CHARTPOS1 would go to line 19 which is an END command. The CHARTSEC1 programming block would then run starting at the first line and the CURPOS4CHART would be greater than 128 which would trigger the GOTO line 3 command. This logic would continue until

the program block reaches Line 9, where 512 is not greater than 512. When position value is not greater than the predetermined value in the programming block the GOTO command is not triggered and the next sequential line runs. In this case the following line would be SETOUT THICKNESS4 THICKNESSFACTORED; this sets the value of THICKNESS4 to the value of THICKNESSFACTORED.

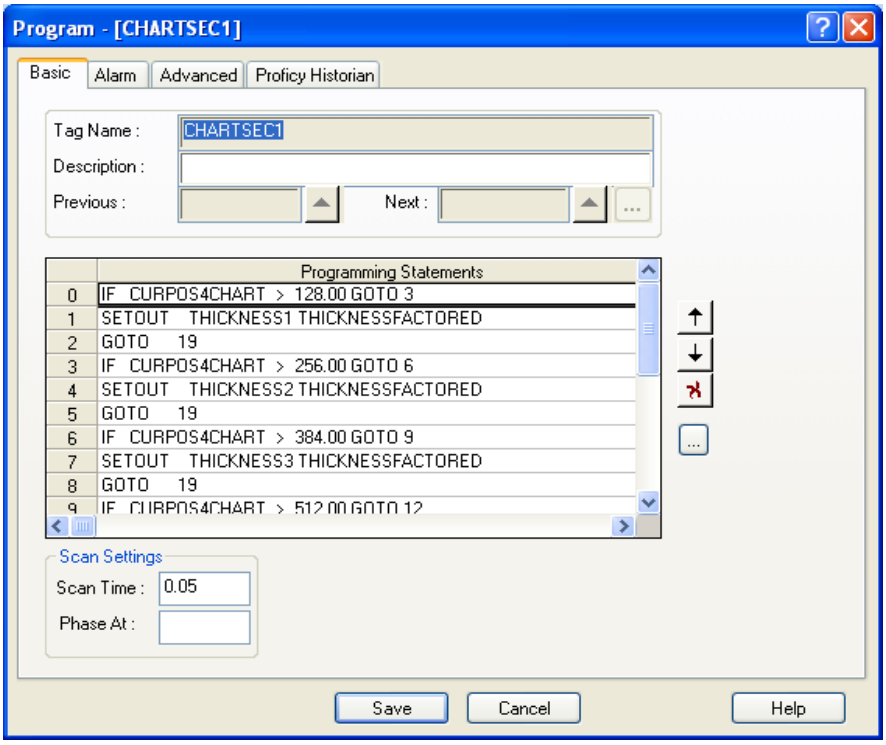

Figure 47. The tag configuration window for a program block being generated in the process database, this program block determines the current position and then associates the thickness measurement with that position.

The program blocks are scanning at a rate of 50 milliseconds, transferring the THICKNESSFACTORED value to 120 different thickness tags based on position. The basic and advanced configuration of one of these thickness tags is shown in Figures 48 and 49 respectively. These are primary analog input tags using the SM2 simulation driver. The addresses all need to be different and were setup as sequential addresses starting at 11 for thickness1 and continuing until address 71 for the positive position thickness values. The negative position thickness values start at address 81 and continue through address 141. One important part of the basic configuration of these thickness tags are that there is no scan time

as they have been configured as exception based. This is easy to enable by checking the "Process by Exception" check box. This conserves system resources and the tags are only updated when the programming blocks set the value of the tag. In order for the thickness tags to work properly with the programming blocks and exception based processing the tags have to be setup in manual mode. The manual mode setting is on the advanced configuration tab of the tag.

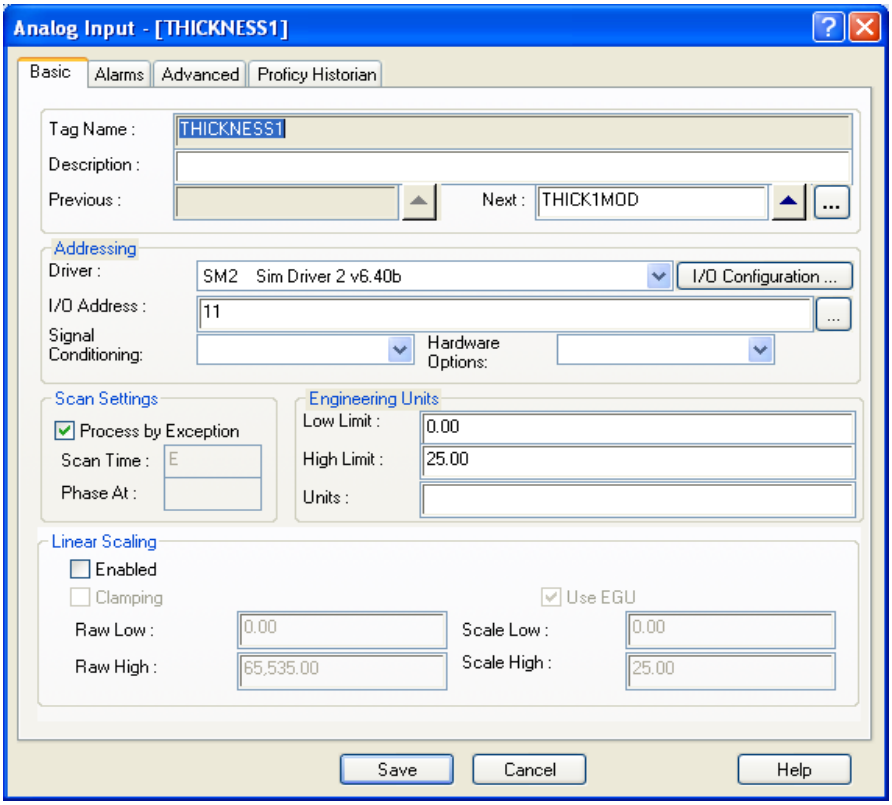

Figure 48. This figure shows the basic tag configuration window for a single thickness tag. The tag is used in generating a single column in the thickness profile chart.

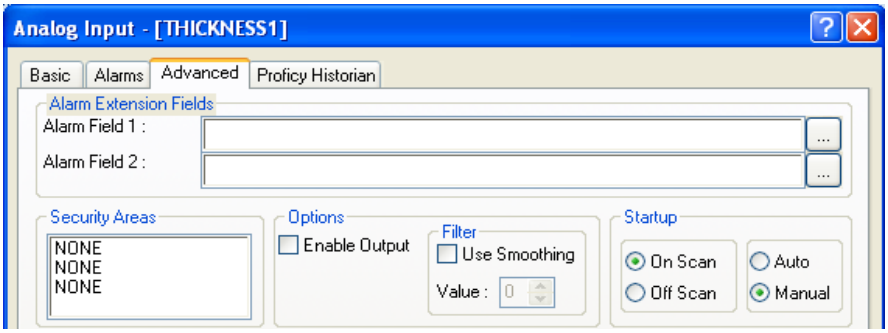

Figure 49. This figure shows the advanced tag configuration window for a single thickness tag. The tag is used in generating a single column in the thickness profile chart.

The data needed to be further manipulated in order to display a column graph that shows the target thickness, a lower limit, upper limit and columns that can go below or above the target thickness value. The “THICKNESS1” analog input starts a tag chain that is used to manipulate the data. The second tag in the chain, THICKMOD1, is a calculation tag that subtracts the TARGETTHICKNESS from the value of the THICKNESS1 tag. The configuration of this calculation tag is shown in Figure 50. The TARGETTHICKNESS tag is an operator entered value based on the product that is being measured. Having the difference between the target thickness and the actual thickness allows the columns to be generated from the center of the y-axis up for positive numbers or down for negative numbers.

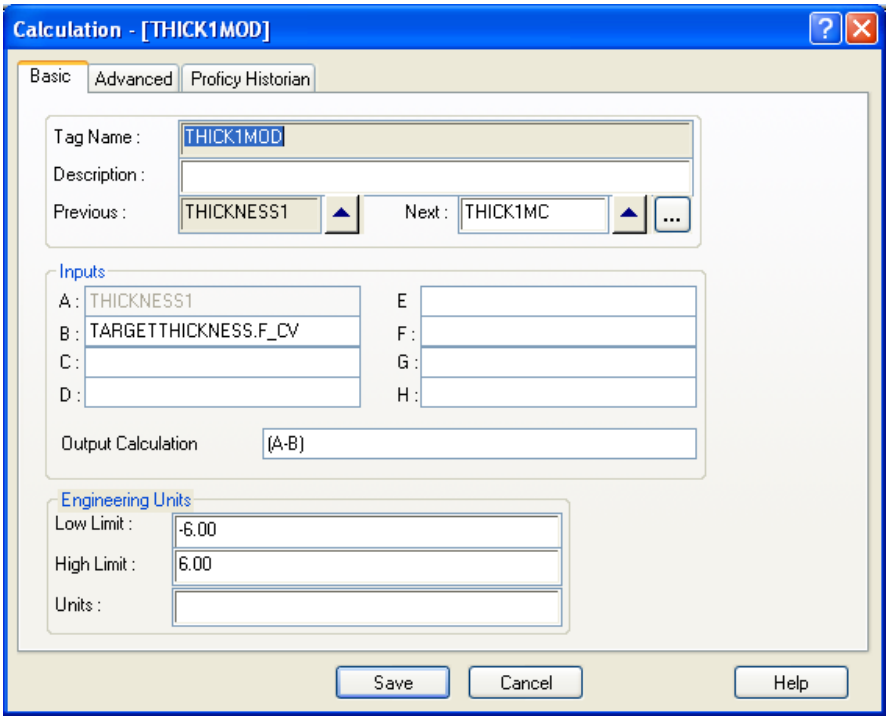

Figure 50. This figure shows the basic tag configuration window for a calculation tag that calculates a new thickness value based on the target thickness and the measured thickness.

The third tag in the chain is another calculation tag that takes the absolute value of the THICK1MOD tag. This value is then passed to the fourth tag in the chain which is an event action tag. The event action tag allows two “if, then, else” statements to be used, which can be seen in Figure 51. In the event action block the value that it receives is first compared to the THICKNESSHIGHCALC value which is the upper thickness limit minus the target thickness. It is

then compared to the THICKNESSLOWCALC value which is the target thickness minus the lower thickness limit. The event action block then opens or closes a digital input tag based on the logic provided. The digital input tag is called THICK1COLOR and is used for coloring each individual column green if the value is within the limits or red if the value is outside of the limits.

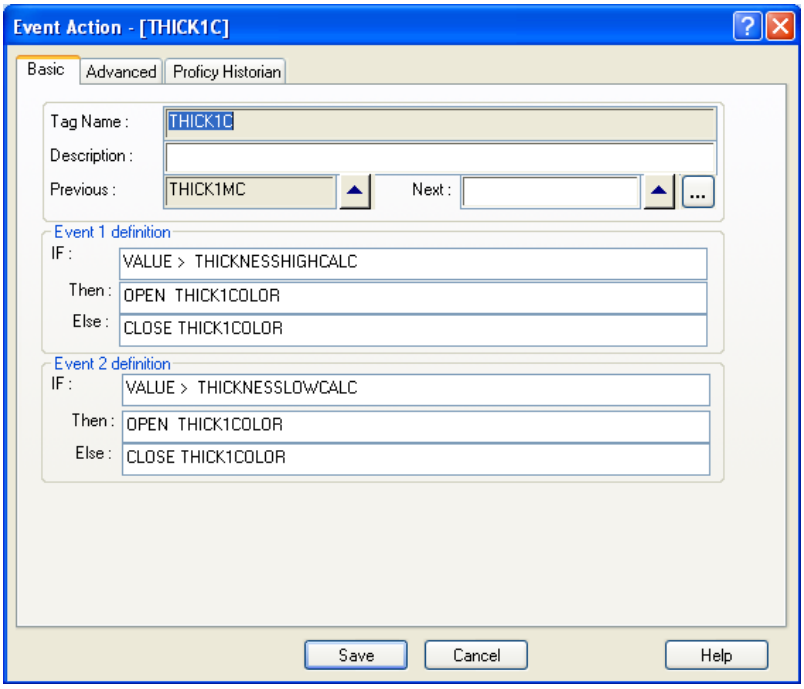

Figure 51. The tag configuration window for an Event Action type tag being generated in the process database.

With the chart display containing 120 columns, each column required a tag chain similar to the one described above. These tags could be generated one at a time, they could be duplicated and then the tag names changed, or the generate feature could be used. The generate function is the fastest and most efficient way of producing multiple tags with sequential numbers in their various fields. The tool ribbon for the process database is shown in Figure 52, above the “blocks” section there are controls for add, modify, delete, show, duplicate, and generate.

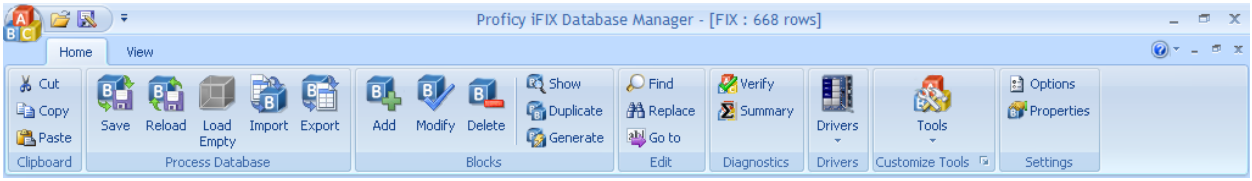

Figure 52. The tool ribbon of the iFix process database.

Selecting the generate icon opens the “Generate Wizard.” The first page of the generate wizard, shown in Figure 53, allows to select an existing tag as a template or use a default template. A single tag can be setup and the configuration can be verified, then the generate wizard can use that tag as the template.

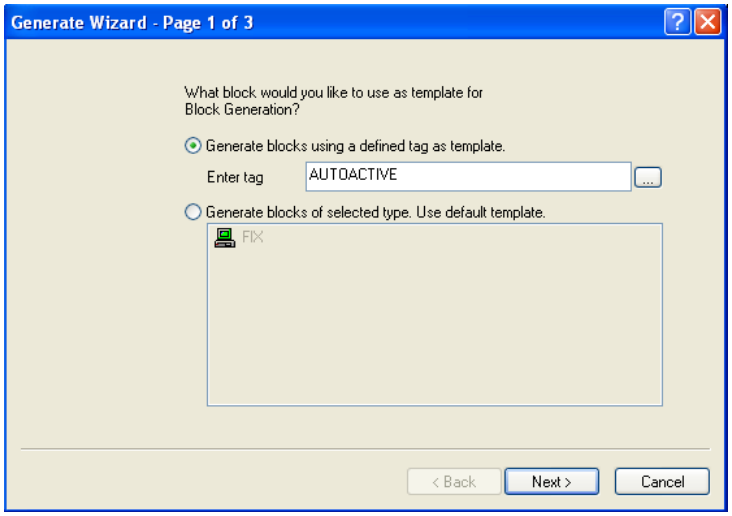
Generate Wizard - Page 1 of 3
What block would you like to use as template for Block Generation?
Generate blocks using a defined tag as template.
Enter tag
AUTOACTIVE
Generate blocks of selected type. Use default template.
FIX
< Back
Next >
Cancel

Figure 53. First page of the generation wizard used to generate a sequnce of tags based on an existing tag or default template.

The second page of the generate wizard, shown in Figure 54, is used to determine the number of tags to be generated and how the tags are named. The tag naming uses a mandatory prefix, a number, and an optional suffix. The numbers are defined with a start value, last value, and how much the generator should increment between values.

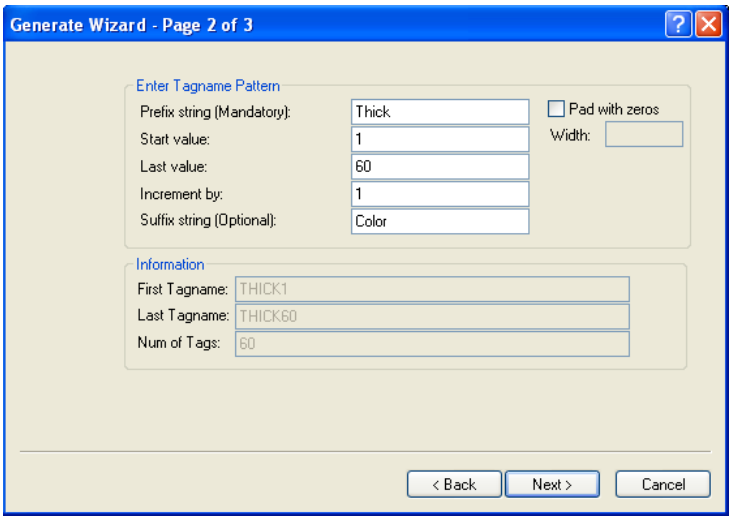

Figure 54. Second page of the generation wizard used to setup the Tagname pattern of the sequence of tags to be generated.

The third page of the generator, shown in Figure 55, allows patterns to be generated for up to five tag fields. The field values can be populated with the same convention as the tag names. The fields will be generated using the prefix, start, end, increment, and suffix provided. The list of tag fields that are available through the generator is extensive, however for this project the I/O address, and next tag fields were the most helpful.

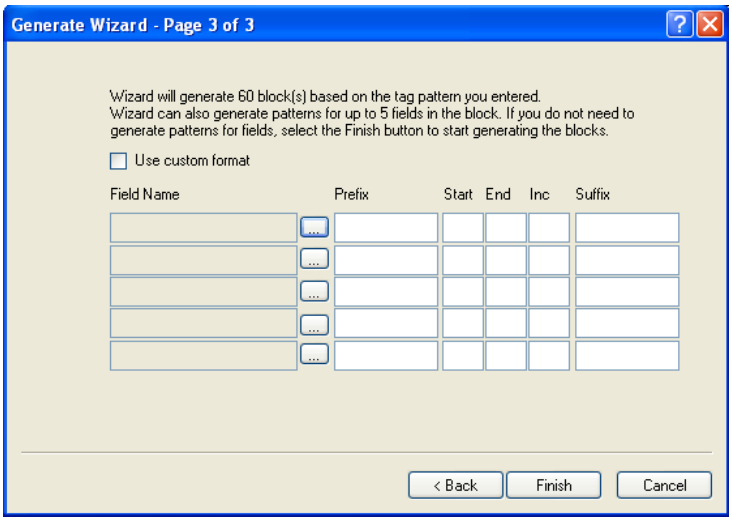
Generate Wizard - Page 3 of 3
Wizard will generate 60 block(s) based on the tag pattern you entered.
Wizard can also generate patterns for up to 5 fields in the block. If you do not need to generate patterns for fields, select the Finish button to start generating the blocks.
Use custom format
Field Name
Prefix
Start
End
Inc
Suffix
< Back
Finish
Cancel

Figure 55. Third page of the generation wizard used to setup the Tag field patterns of the sequence of tags to be generated.

3.5 Graphical User Interface

The graphical user interface allows users to interact with the machinery, equipment, and electronic devices. The graphical user interface uses a non-text based display made up of buttons, icons, and other visual indicators. The hardware of the graphical user interface is a touchscreen monitor. The iFix HMI software is used to develop the on screen visuals of the GUI.

Touchscreen Display

The touchscreen display is a PLANAR model PXL2230MW 22” LCD monitor. The monitor uses an optical touchscreen technology and interfaces using a USB connection. The monitor simply needed to be connected and a driver needed to be installed. In order to setup the

monitor in a convenient location for the operator an Ergotron MX wall mounted monitor arm was installed. An image of the Ergotron MX is shown in Figure 56.

Figure 56. Image of an MX wall mounted monitor arm from Ergotron Website [18].

iFix Human Machine Interface (HMI)

Development of the iFix HMI consists of linking analog tags to data stamps, digital tags to onscreen buttons, and generating animations as needed. The toolbox displayed in Figure 57 is the primary method for placing objects, adding animations, and alignment. There is a time button for placing an on screen time stamp, a date stamp for placing an on screen date. There are various generic shapes that can be placed on the screen and a tool for making more complex shapes. There is a datalink stamper that can be used to easily add text that is linked to a tag in the process database. The datalink can be setup as numeric or characters depending on the type of data. The color palette allows for a wide variety of options for all object, text, and background colors. There are built in chart experts for simple trend line, X-bar, R and S charts.

The fourth row of icons in the toolbox provides alignment options that can be used to precisely position objects on the screen.

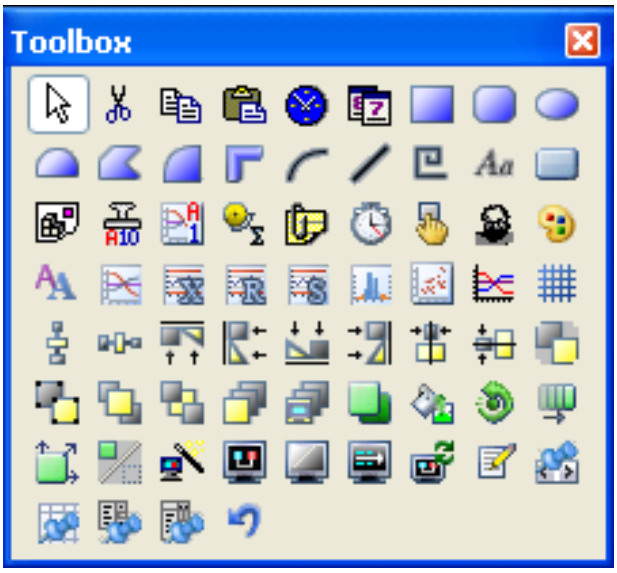

Figure 57. Toolbox used in iFix HMI generator.

One of the simplest animations is through the use of the datalink stamper. The stamper allows a tag value to be linked to a text block. When the text block is generated the number of characters or the number of digits before and after the decimal place can be set. The text will then automatically update when the linked tag updates. The auto scan settings shown in Figure 58 are few examples of the text blocks that are provided by the datalink stamper. While in development mode the text blocks display pound signs because the links are not live until the mode is switched back to run mode.

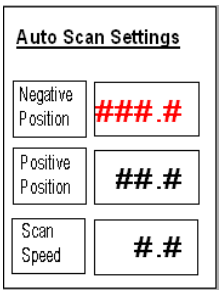

Figure 58. An example of three different datalinks used for entering settings through the HMI.

When in development mode right clicking on an object brings up the menu displayed in Figure 59. There are many options available in this menu for modifying the object or editing the animations or script associated with the object.

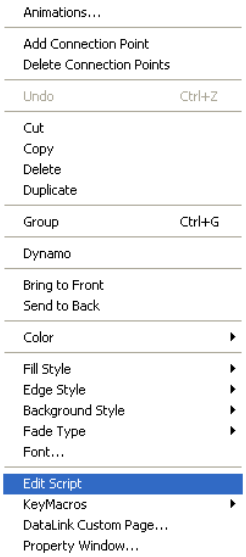

Figure 59. The menu that appears when an object is right clicked while in development mode.

Another useful feature available through the right click menu is the property window, shown in Figure 60. The property window shows the object name, text displayed on the object, coloring information, position information, and other object information.

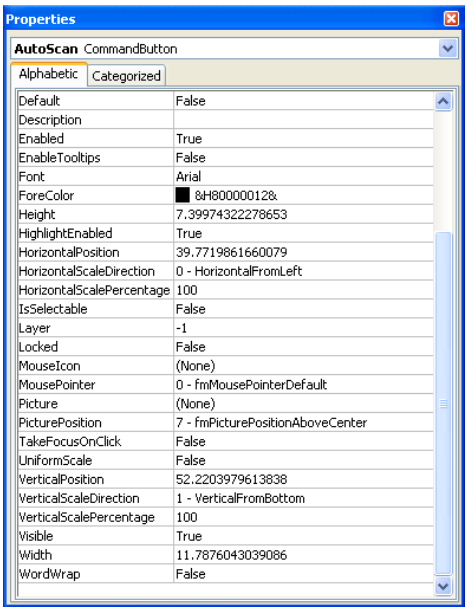

Figure 60. The properties window shows various object properties while in development mode.

The basic animation window shown in Figure 61 is used to configure the animations of all on screen objects. Through this window the edge and background color can be animated. The basic animations also include object position, scaling, rotation, and visibility. The window also allows access to the advanced animations and click commands. Each type of animation is used in this project for animating the on screen objects, with some of the objects having more than one animation.

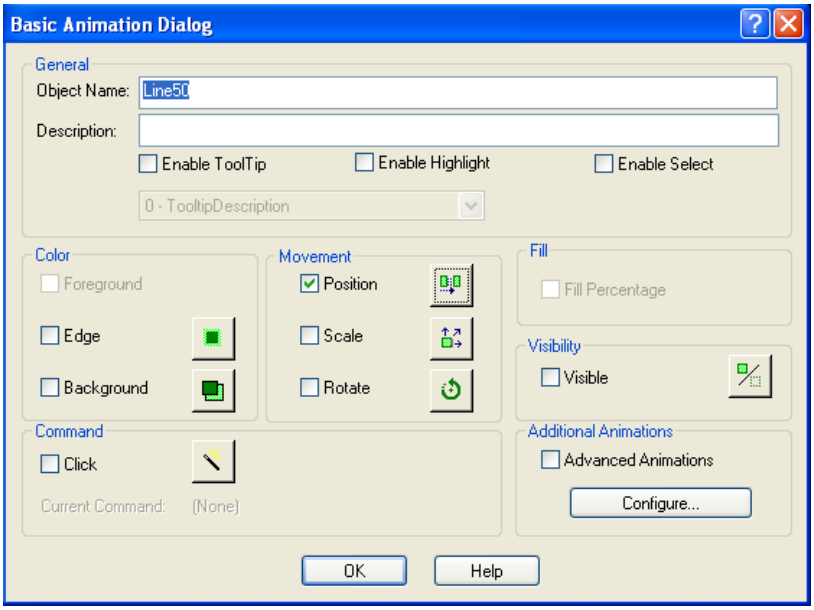

Figure 61. The basic animation dialog window is used for configuring various object animations on the HMI.

An example of the position animation expert being used is shown in Figure 62. This example is for the high thickness limit. The line that represents the high thickness limit moves vertically based on the current tag value of the THICKNESSHIGHCALC tag. The input values can be set to different limits than the tag limits or the tag limits can be fetched at runtime. The position type can be set as relative or absolute. When the relative position type is selected the position move is based on the starting point of the object. If the absolute position type is selected than the position move is based off the top left corner of the screen. The vertical position output values determine how far the object moves based on the value of the data source.

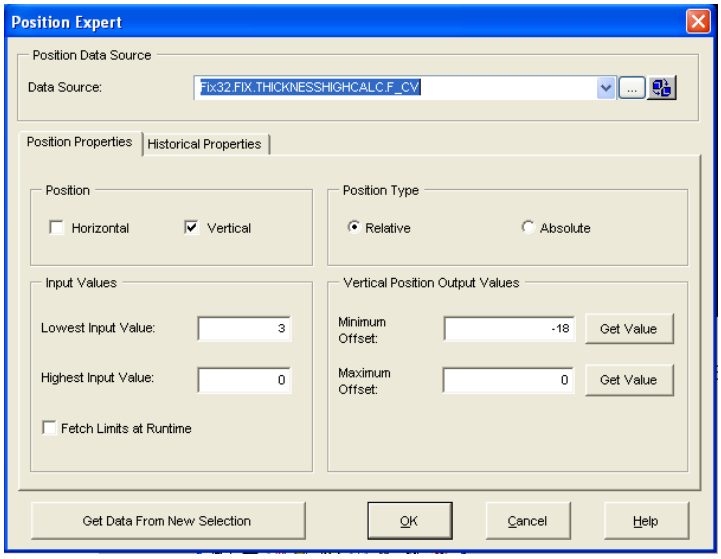

Figure 62. The position expert window is used to configure animations that change the position of an object based on the provided data source.

When implementing a toggle button for a digital input the "Click" command box on the basic animations window can be checked off. When using the "Click" command a secondary window opens, shown in Figure 63, that allows various commands to be selected. When the object is clicked in run mode the commands will be completed. In this project the buttons use a simple toggle digital tag command that will toggle a tag on if it was previously off and vice versa.

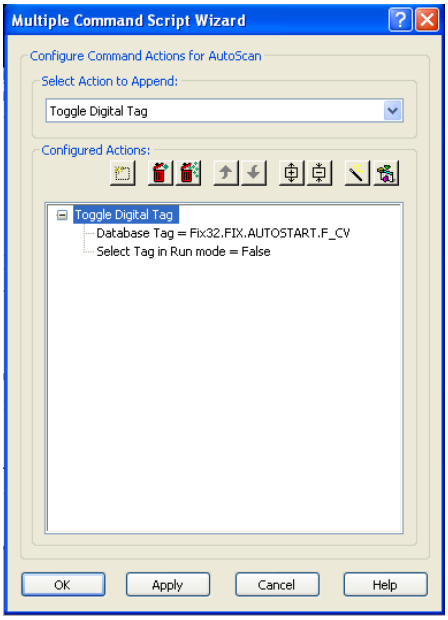

Figure 63. The multiple command script wizard is used to setup commands that should be issued when an object is clicked.

The buttons on this project HMI have also been animated using the advanced animations window shown in Figure 64. The buttons have been configured to display a grey background color when not active and to turn green when active. This animation also could have been completed using the basic background color animation.

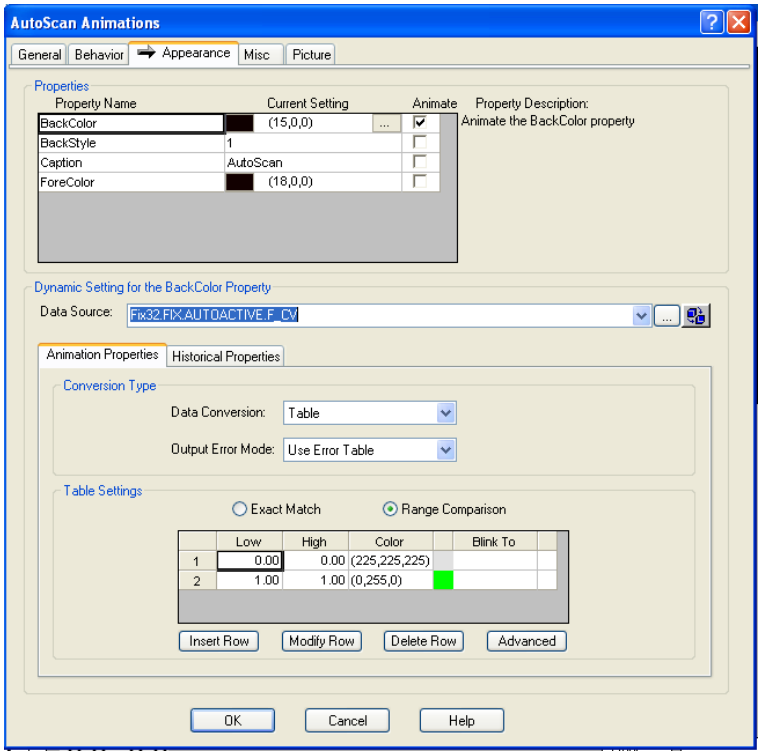

Figure 64. The advanced animations window showing that the object appearance changes from grey to green based on a digital input tag value.

The individual columns of the chart display each require four animations using two different data sources and two different objects. Each column is made up of two columns stacked on one another and are configured in such a way that if one column is active the other is not being displayed. The first animation uses the scale expert window shown in Figure 65. The current value of the THICK1MOD is used to determine the height of the column. There is a scaling animation for each of the two columns with each being the inverse of the other. When the value of THICK1MOD is a positive number the top column will scale from bottom to top growing, the bottom column will disappear.

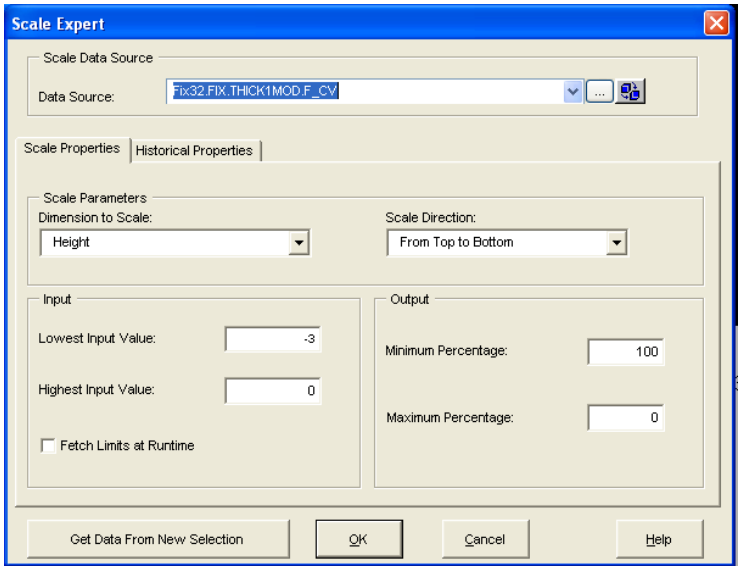

Figure 65.The scale expert window is used to configure animations that change the object scale based on the provided data source.

The second animation uses the edge color expert which is displayed in Figure 66. The edge color is displayed as red or green based on the current value of the THICK1COLOR tag. This tag is a digital input tag that is either on or off based on whether the thickness value is within the thickness limits that were set by the operator.

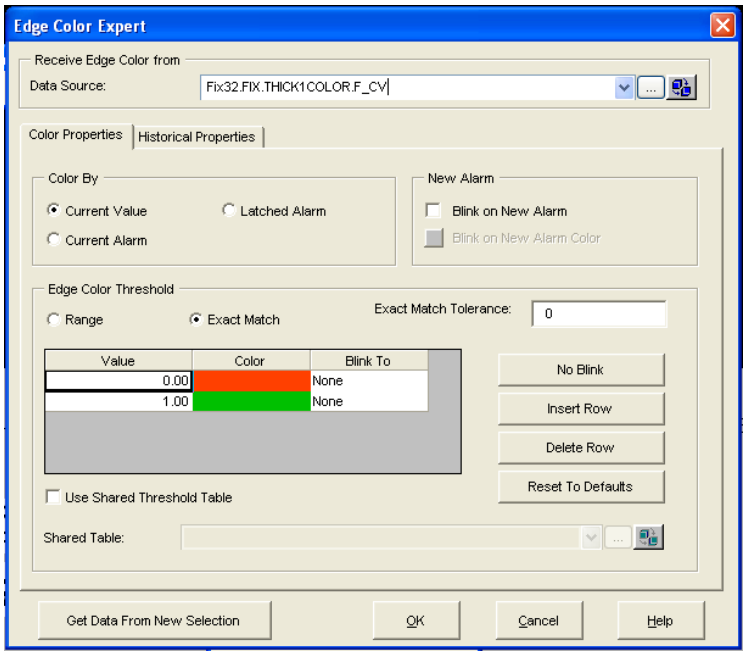

Figure 66.The edge color expert window is used to configure animations that change the color of an object based on the provided data source.

The finished graphical user interface mounted on the adjustable arm is shown in Figure 67. The finished display shows the where the scanner currently is, the target thickness, upper and lower limits and current thickness. The chart on the display provides a thickness profile of the web that is easy to interpret and can quickly show if the web is outside of specifications.

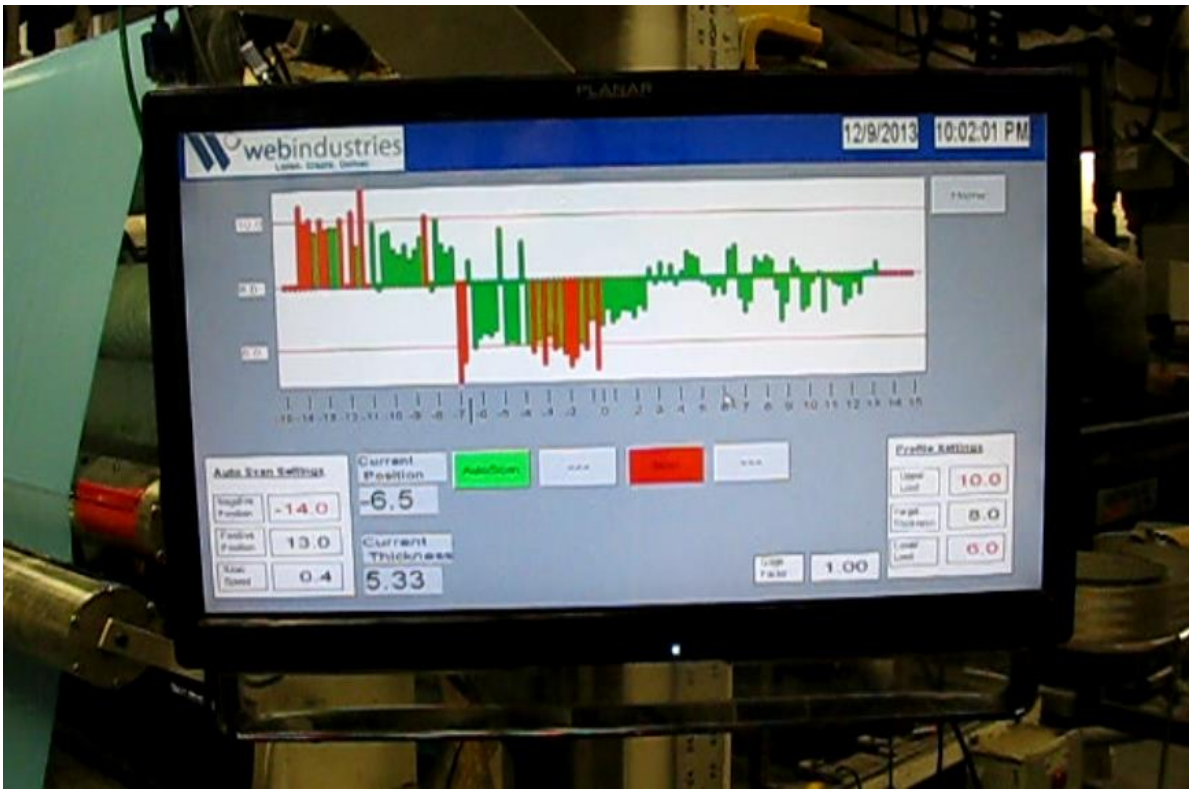

Figure 67. This picture shows the touchscreen monitor mounted on the MX ergotron wall mounted monitor arm. The monitor is displaying the thickness profile of a 30" wide web.

4 System Limitations and Future Improvements

Although the system has been completed there is still more work to be done. The system as it stands has a few issues and opportunities for improvement. The first issue is that the thickness value varies depending on the direction the scanner is travelling in. This will need to be investigated and then corrected as it has a direct impact on the accuracy of the thickness profile that is displayed. A second issue that needs to be corrected is an intermittent animation

problem that causes the chart columns to disappear for a single pass of the scanner. A third issue with the system is that some of the columns in the chart are updated multiple times as the scanner passes them, while others are missed. The column update problem may be corrected by adjusting scan times of the programming blocks.

The first improvement that needs to be made to the system is to increase the accuracy of the thickness measurements. This may be accomplished by correcting issues with the current measurement system. However there are other thickness measurement techniques that would provide an increased precision and accuracy. With this system the thickness gauge can be easily replaced by establishing communication with the new thickness gauge and replacing the data source for the THICKNESSRAW tag. The second step for improving the thickness scanner will be to link the thickness tags to a Historian server. Once the tags are being collected in a Historian server the data can be queried and trends for machine direction variation can be examined further increasing the usefulness of the scanner. The third step would be to expand the graphical user interface adding different types of charts that can be used for statistical process control. The charts that may be implemented include a historical display indicating the historical thickness data regardless of position, a histogram showing the thickness distribution, and machine direction thickness charts indicating the historical thickness for specific scanner positions. One last improvement may be to increase the resolution of the thickness profile chart with columns representing less than one quarter of an inch.

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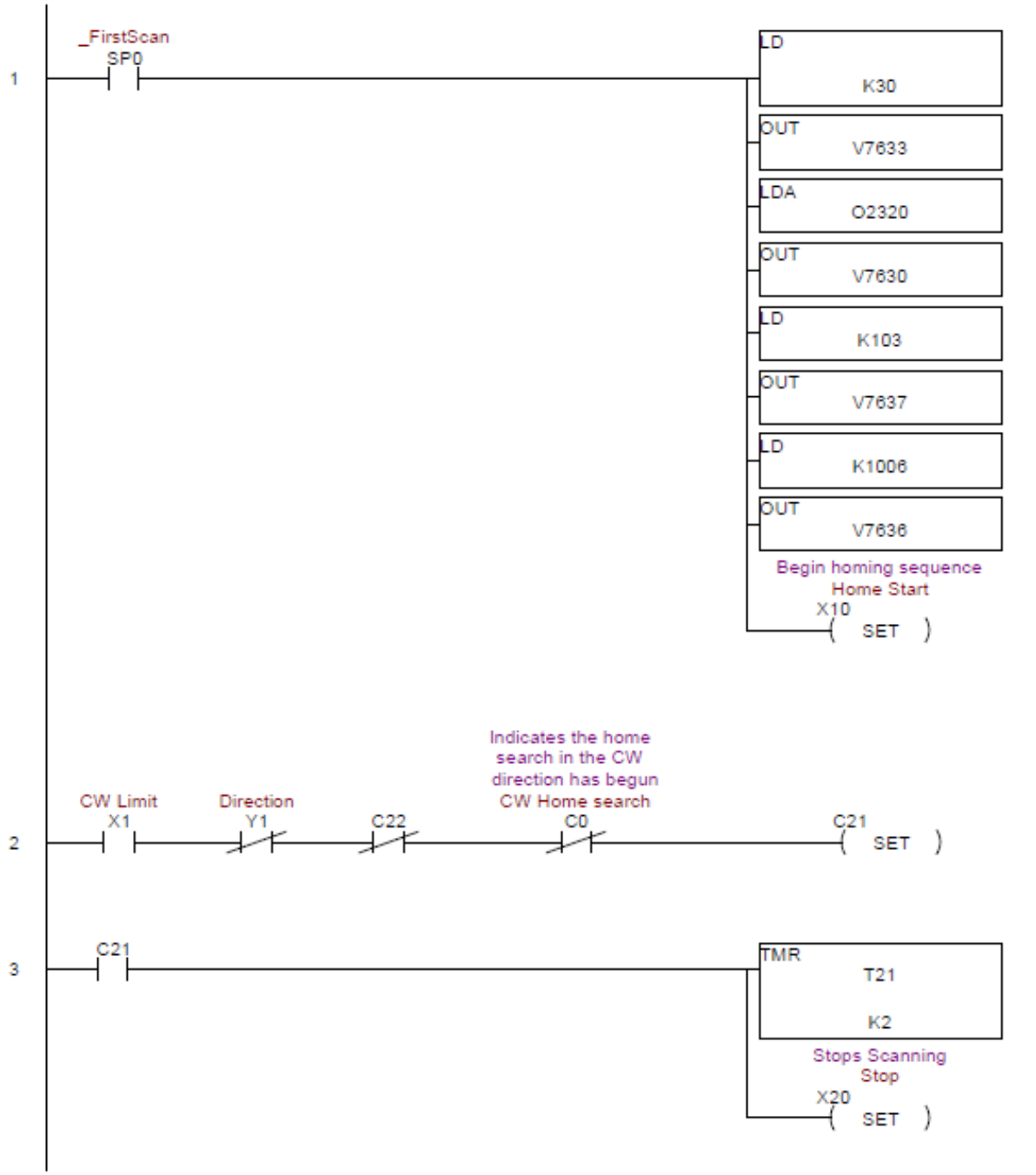
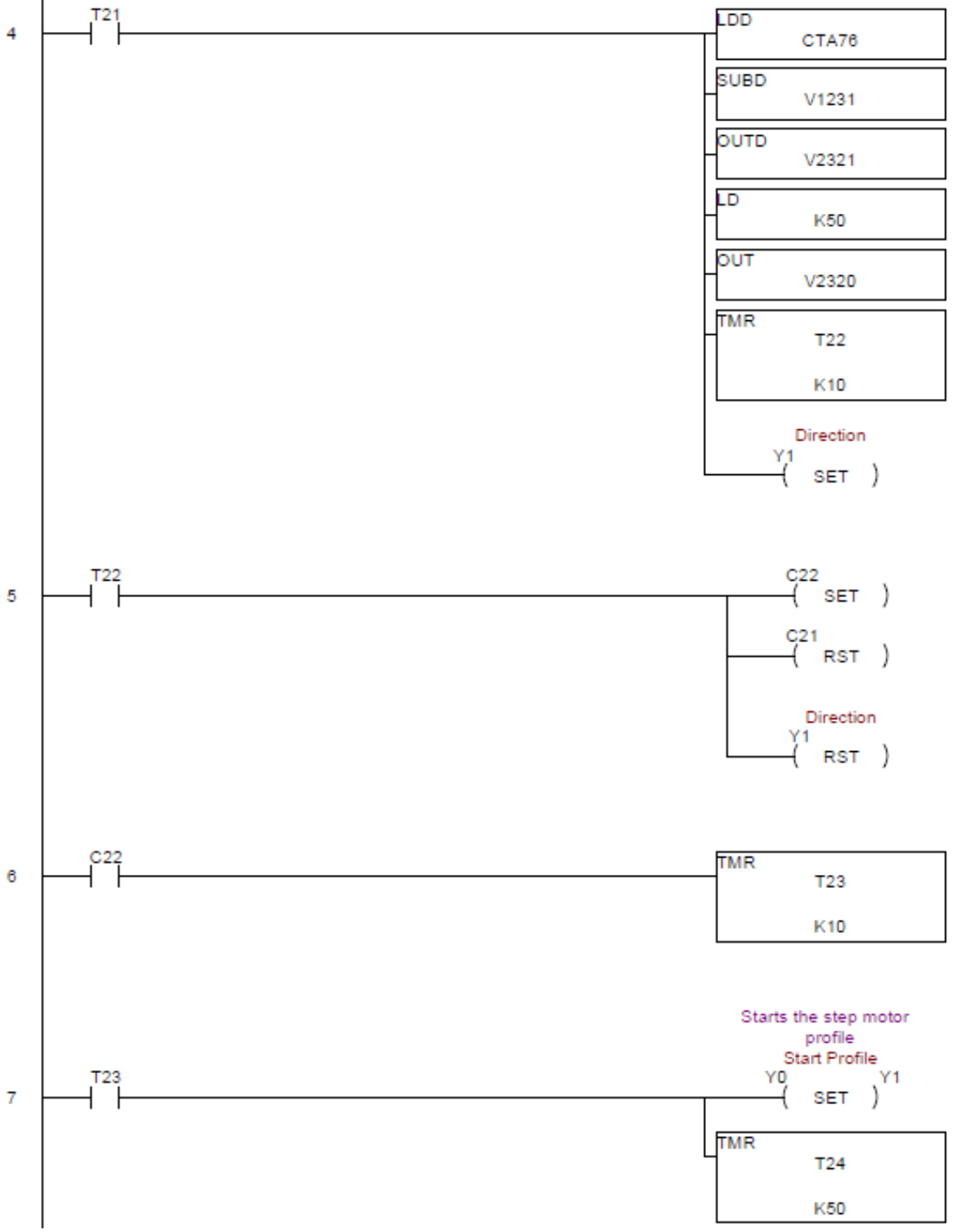
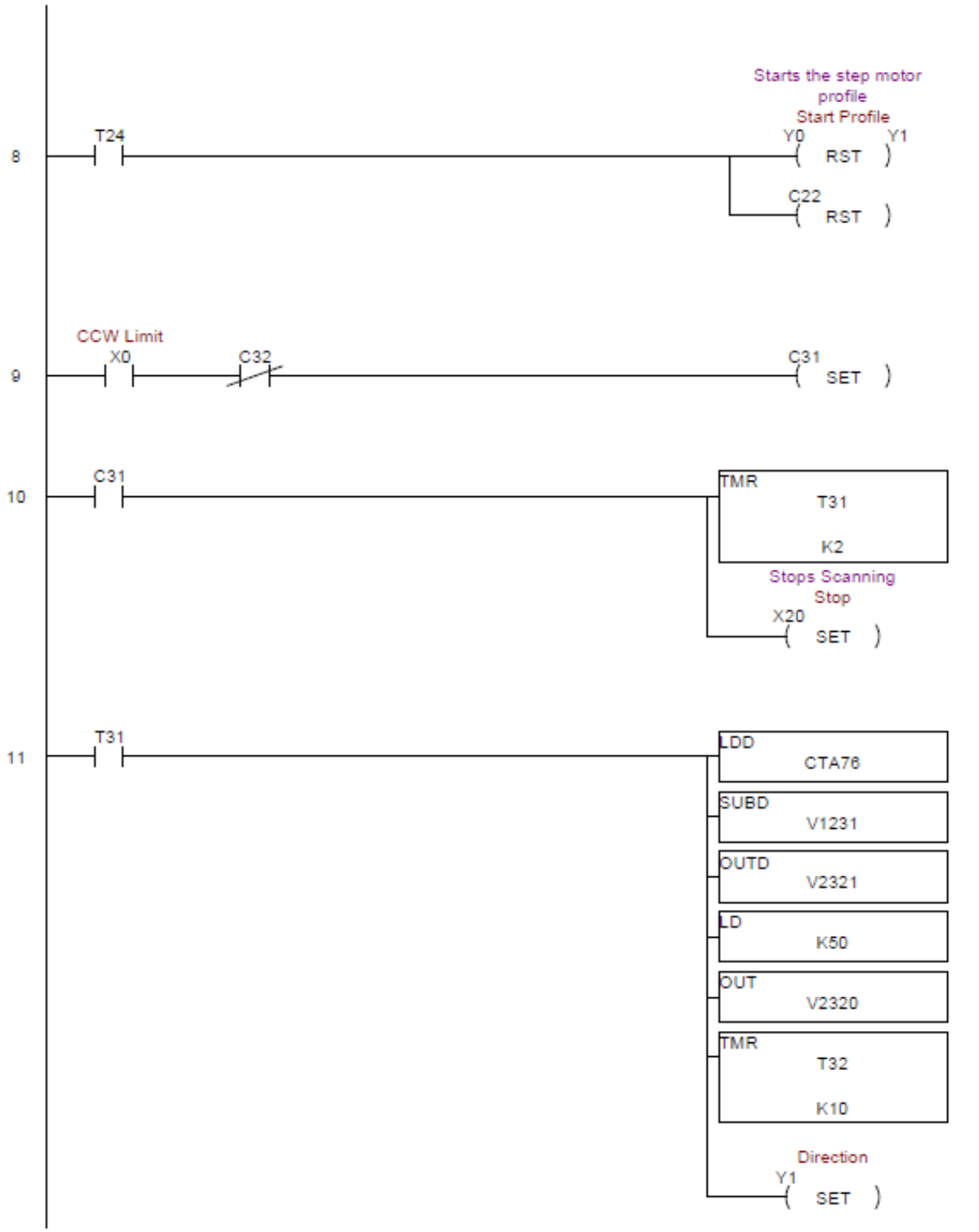
6 Appendix A PLC program

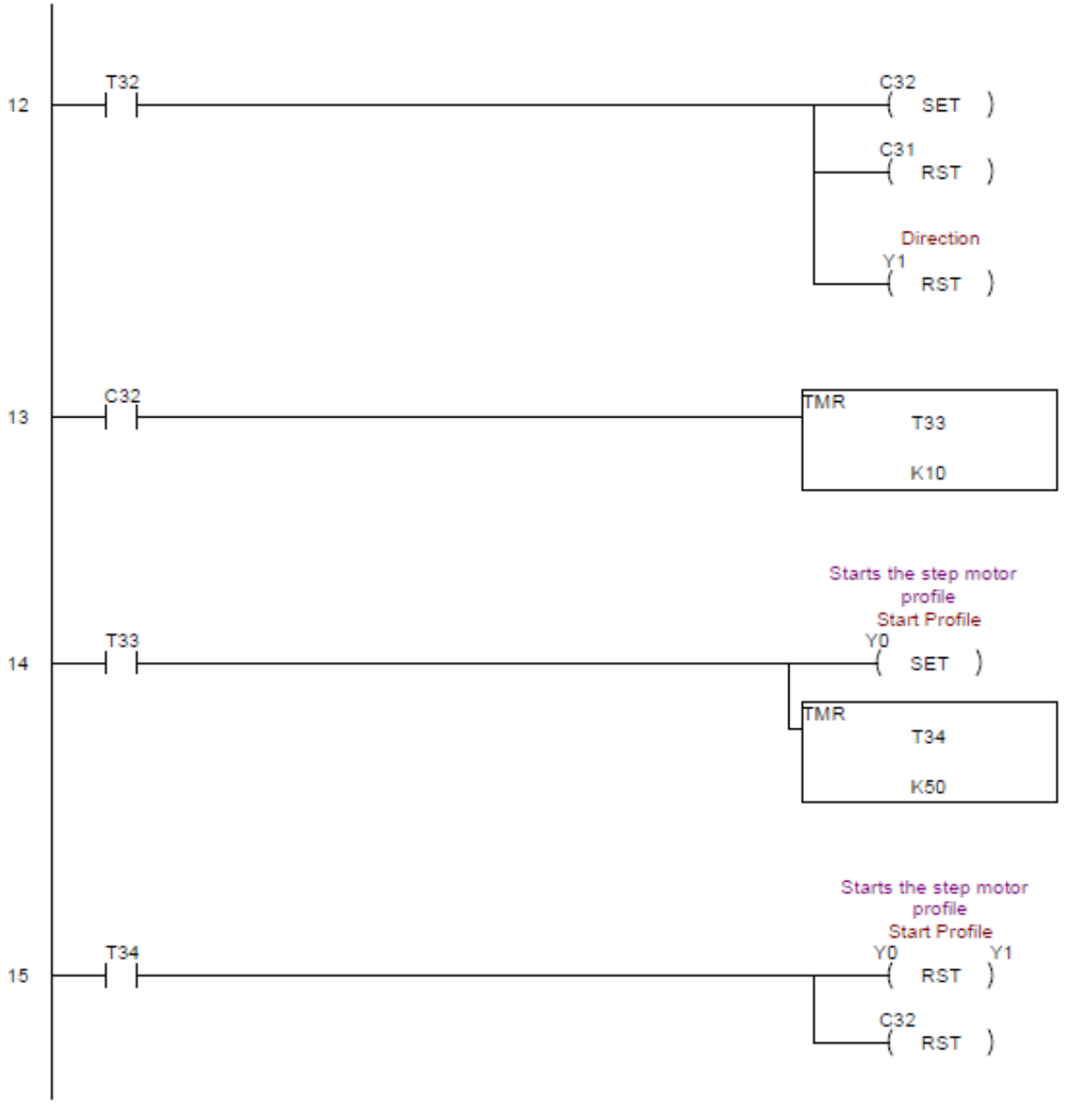
12/15/2013	Line 2 Thickness Scanner	05	line2 scanner 12_12

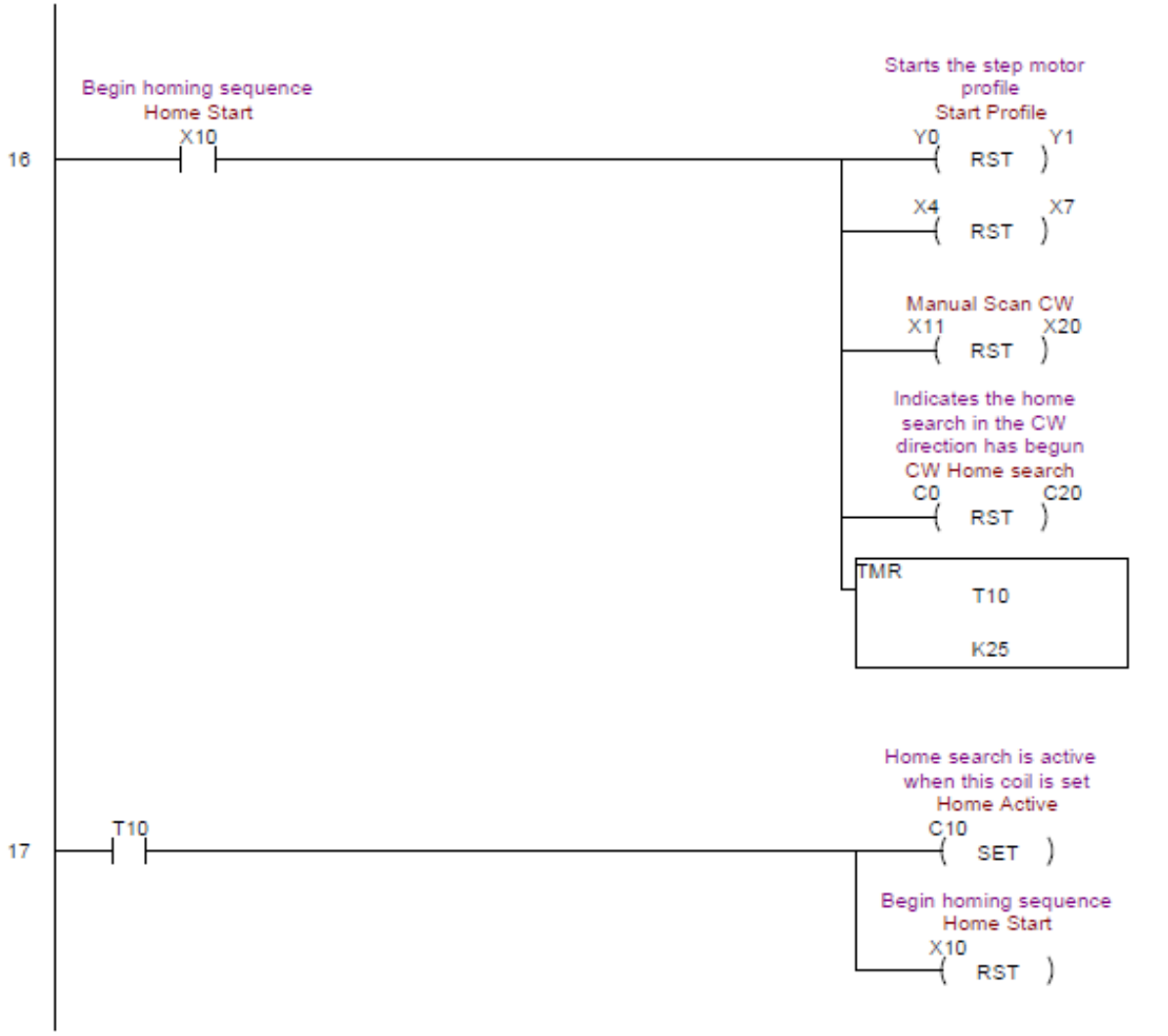
Path: c:\directsoft5\projects\line 2 scanner projects\line2 scanner 12_12.prj
Save Date: 12/12/13 17:21:04
Creation Date: 12/12/13 17:21:03
PLC Type: 05
Class ID: DirectLogic 05 Series
Link Name: Line2Scanner
Description: Line 2 thickness scanner
Programmer: Ray Stockwell

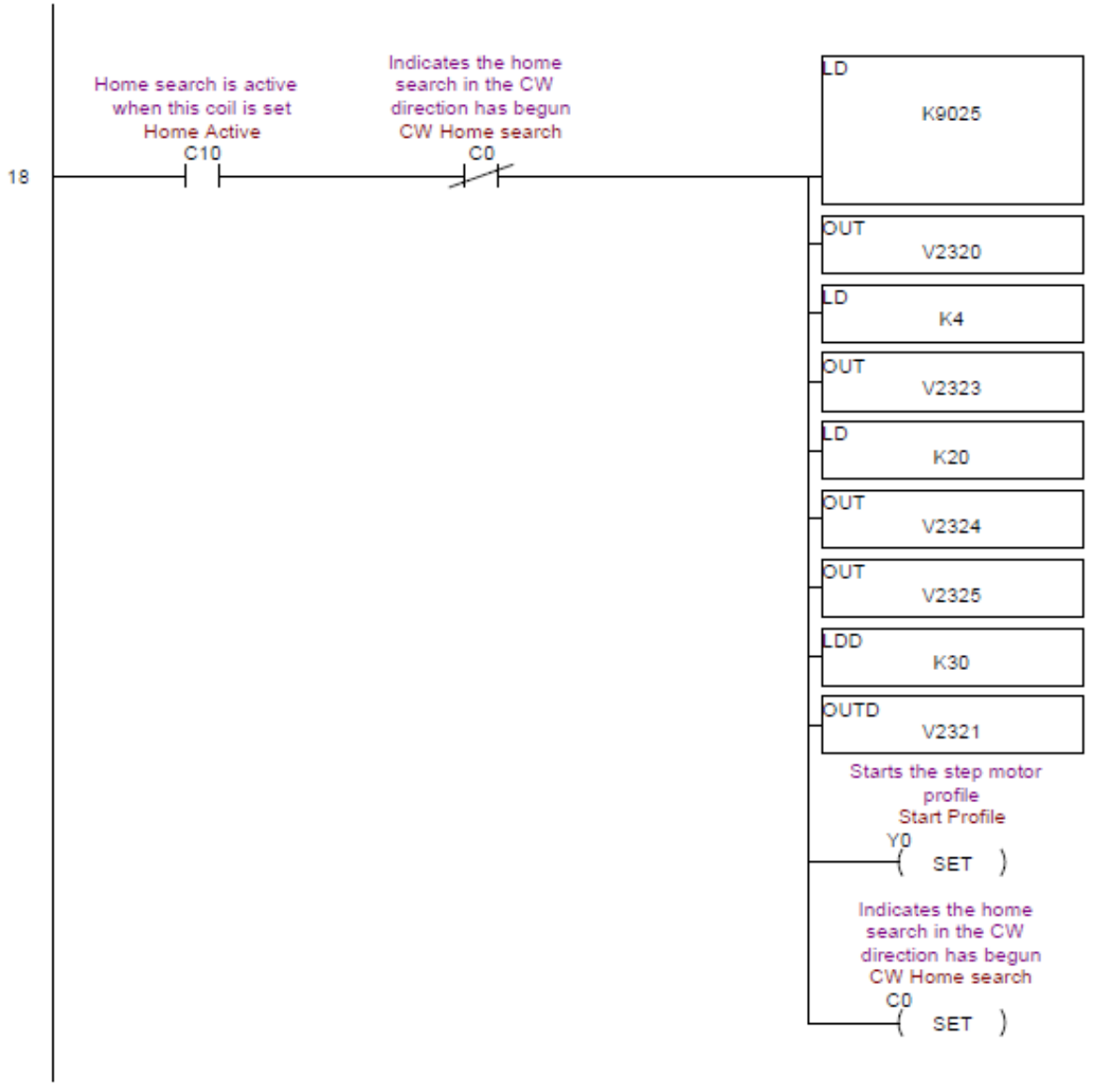

_FirstScan
SP0
1
LD
K30
OUT
V7633
LDA
O2320
OUT
V7630
LD
K103
OUT
V7637
LD
K1006
OUT
V7636
Begin homing sequence
Home Start
X10
SET
Indicates the home search in the CW direction has begun
CW Home search
CW Limit
X1
Direction
Y1
C22
C0
C21
SET
2
C21
3
TMR
T21
K2
Stops Scanning
Stop
X20
SET

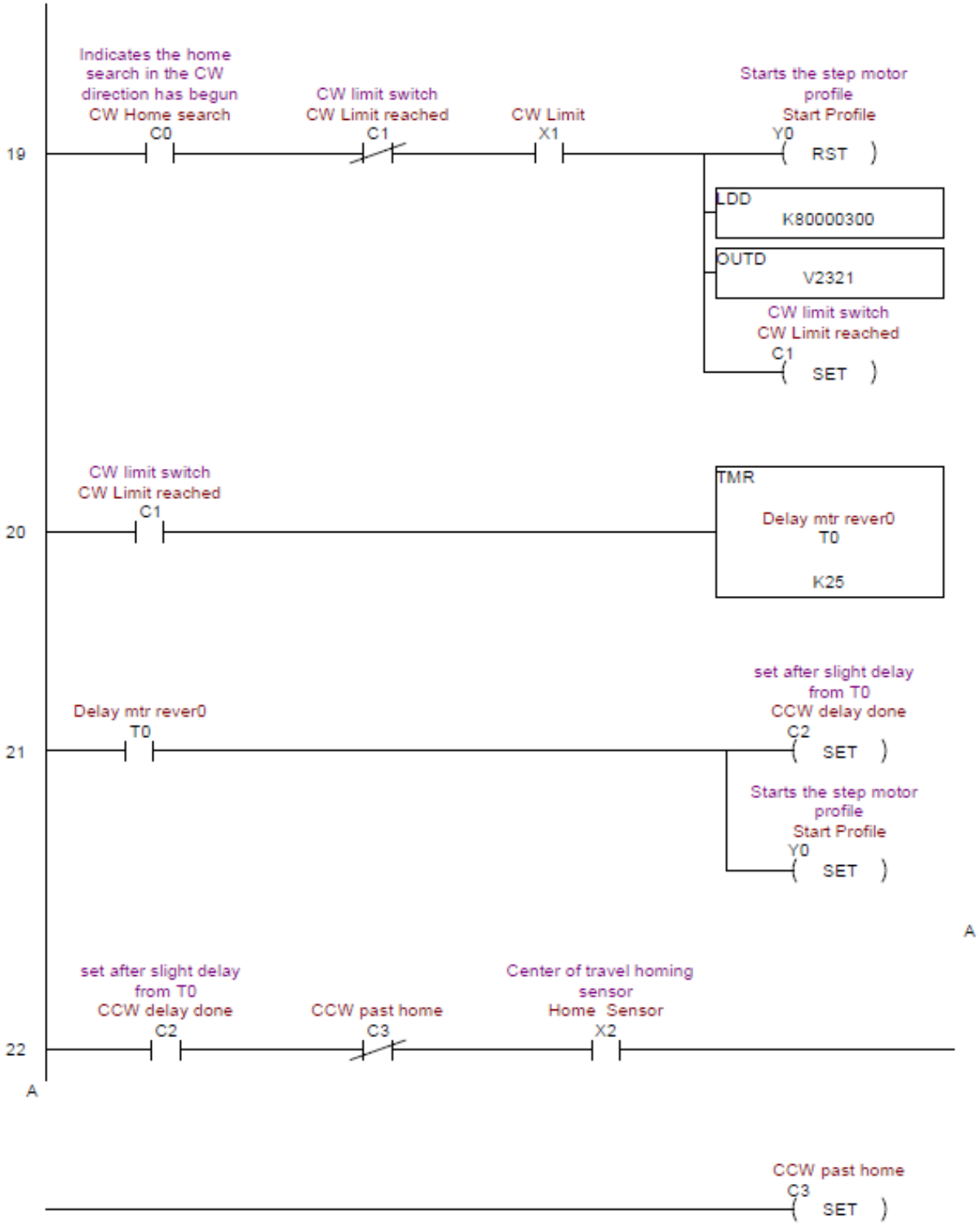

4
T21
LDD
CTA76
SUBD
V1231
OUTD
V2321
LD
K50
OUT
V2320
TMR
T22
K10
Direction
Y1
SET
5
T22
C22
SET
C21
RST
Direction
Y1
RST
6
C22
TMR
T23
K10
Starts the step motor profile
Start Profile
7
T23
Y0
Y1
SET
TMR
T24
K50

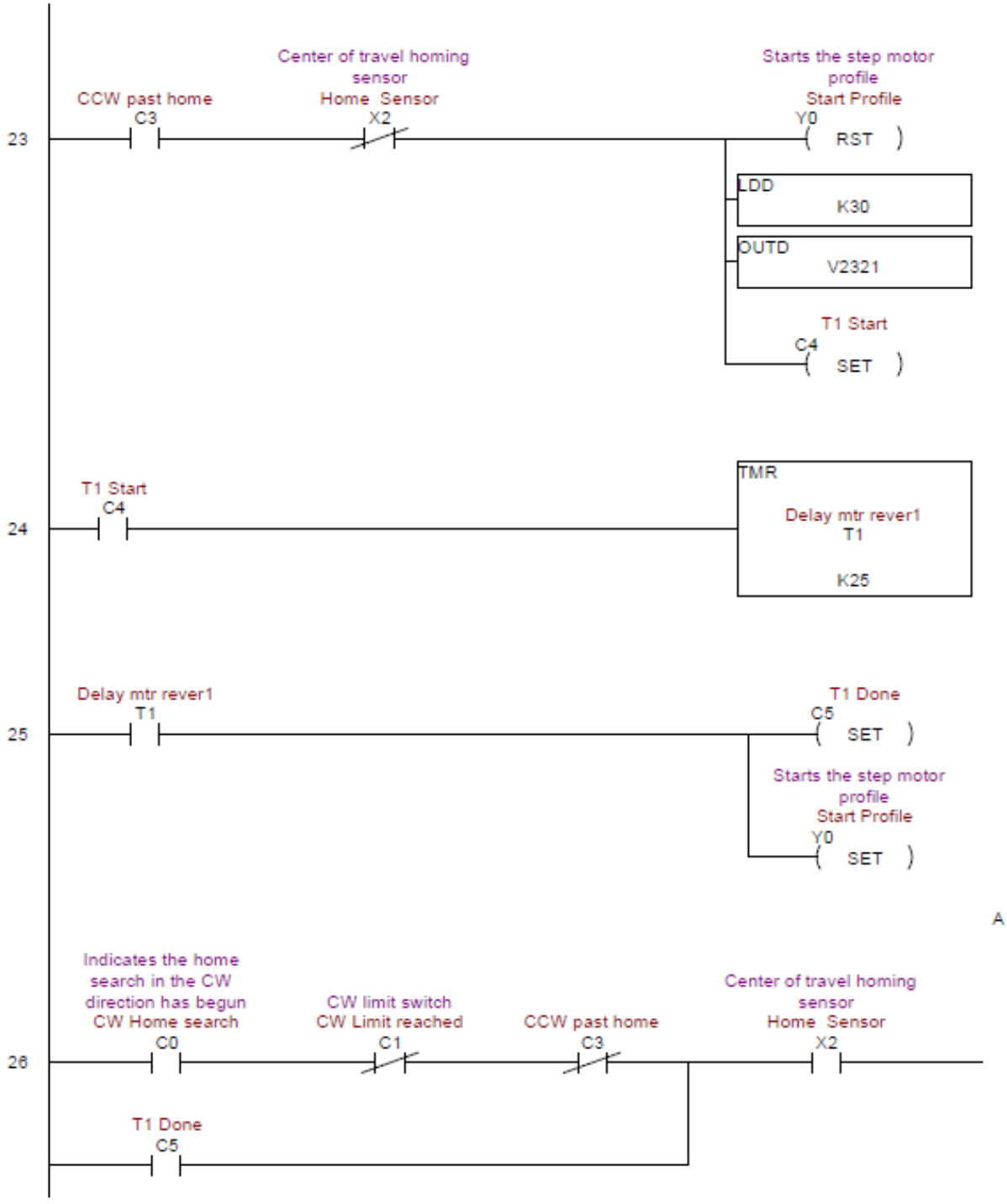

Starts the step motor profile
Start Profile
8
T24
Y0
RST
Y1
C22
RST
CCW Limit
X0
C32
9
C31
SET
10
C31
TMR
T31
K2
Stops Scanning
Stop
X20
SET
11
T31
LDD
CTA76
SUBD
V1231
OUTD
V2321
LD
K50
OUT
V2320
TMR
T32
K10
Direction
Y1
SET

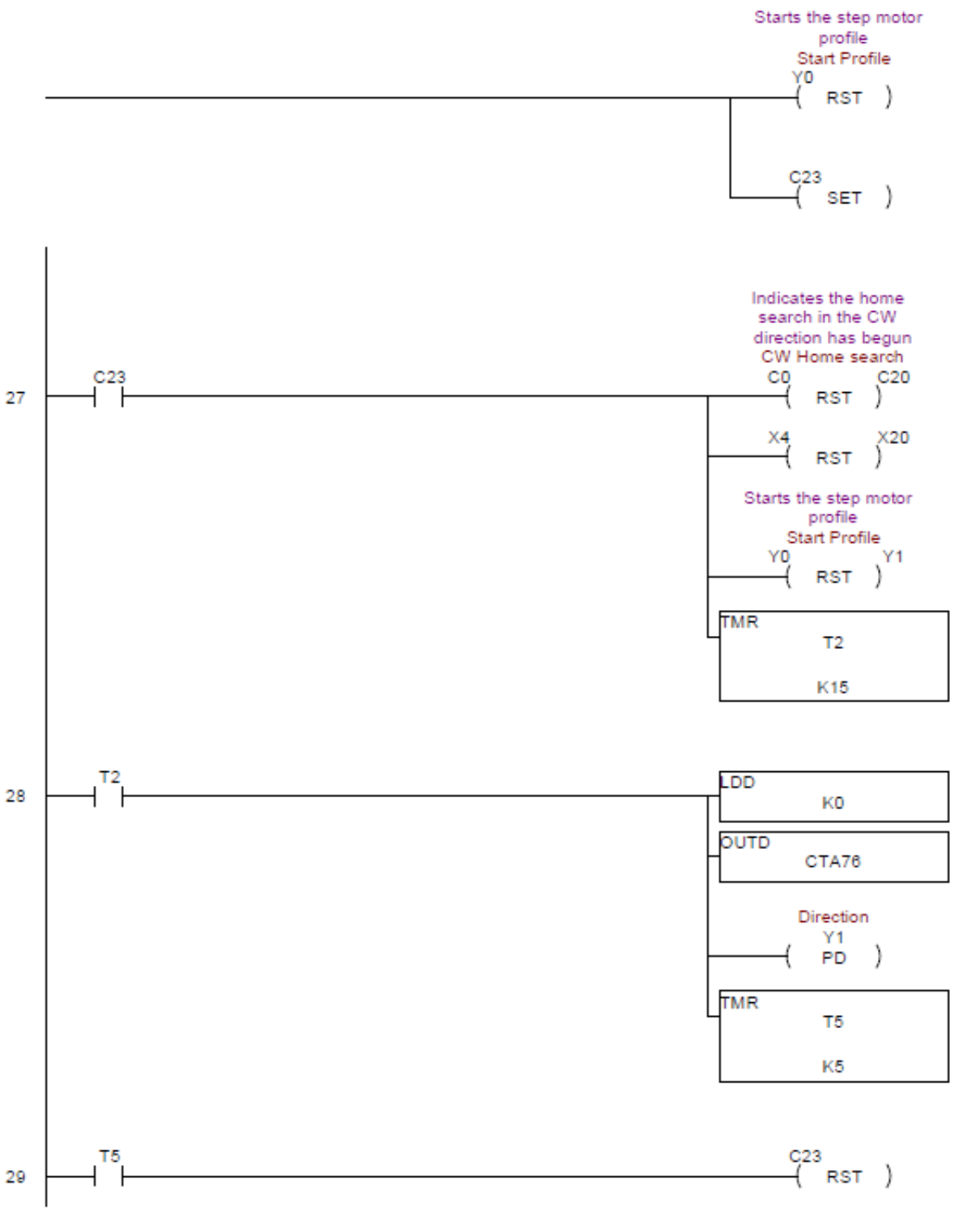

12
T32
C32
SET
C31
RST
Direction
Y1
RST
13
C32
TMR
T33
K10
Starts the step motor profile
Start Profile
14
T33
Y0
SET
TMR
T34
K50
Starts the step motor profile
Start Profile
15
T34
Y0
Y1
RST
C32
RST

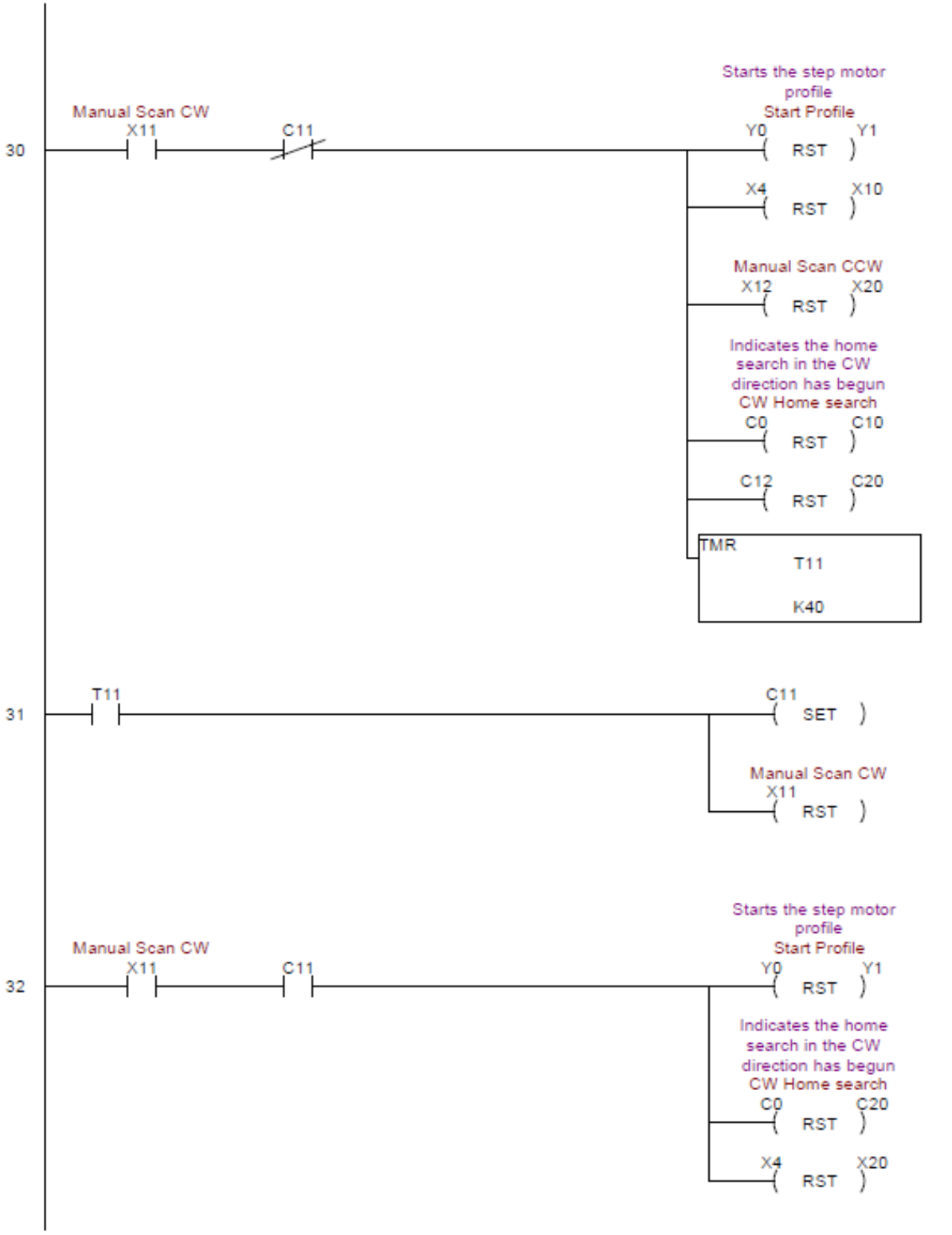

16
Begin homing sequence
Home Start
X10
Starts the step motor profile
Start Profile
Y0
RST
Y1
X4
RST
X7
Manual Scan CW
X11
RST
X20
Indicates the home search in the CW direction has begun
CW Home search
C0
RST
C20
TMR
T10
K25
17
T10
Home search is active when this coil is set
Home Active
C10
SET
Begin homing sequence
Home Start
X10
RST

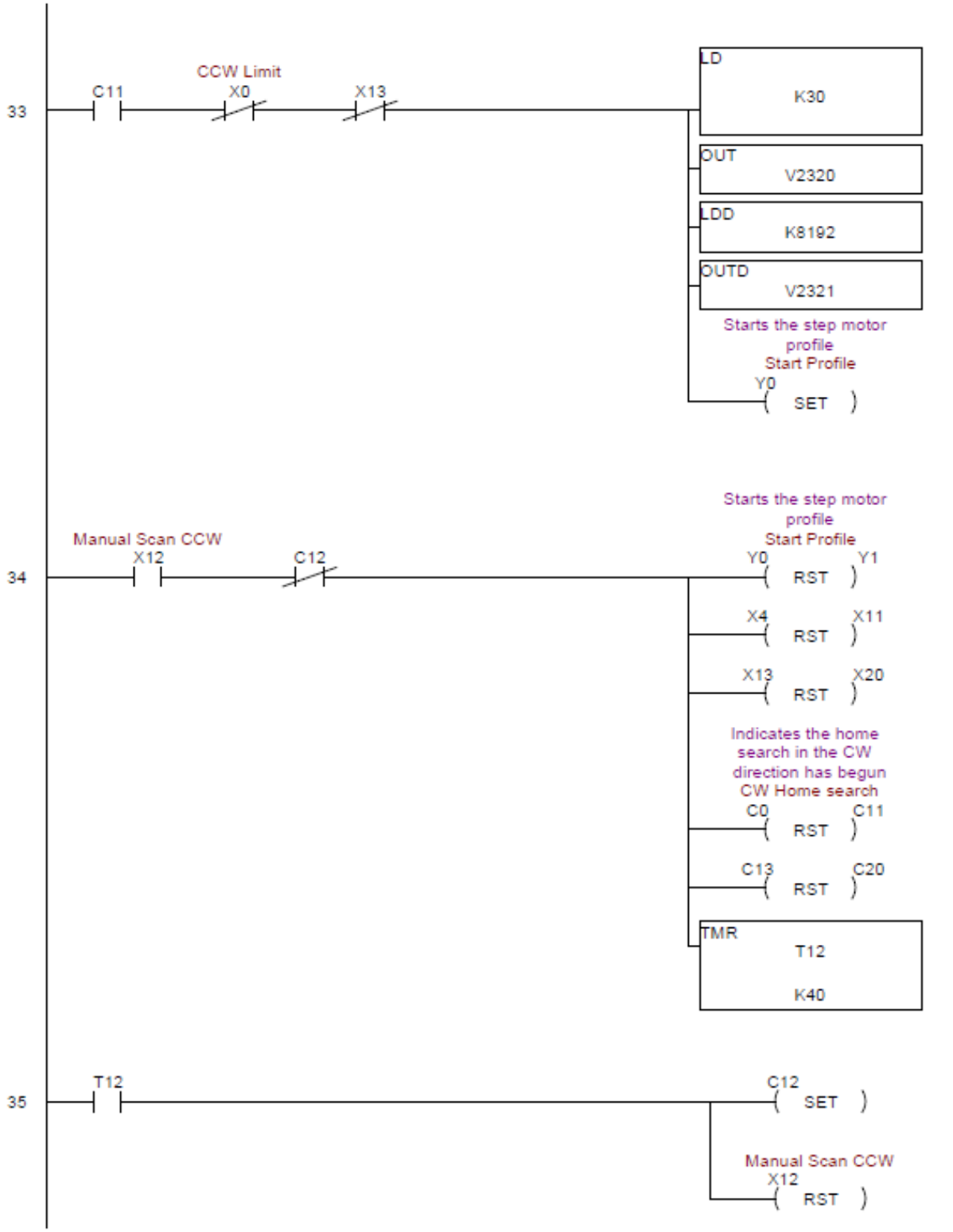

18
Home search is active when this coil is set Home Active
C10
Indicates the home search in the CW direction has begun CW Home search
C0
LD
K9025
OUT
V2320
LD
K4
OUT
V2323
LD
K20
OUT
V2324
OUT
V2325
LDD
K30
OUTD
V2321
Starts the step motor profile Start Profile
Y0
SET
Indicates the home search in the CW direction has begun CW Home search
C0
SET

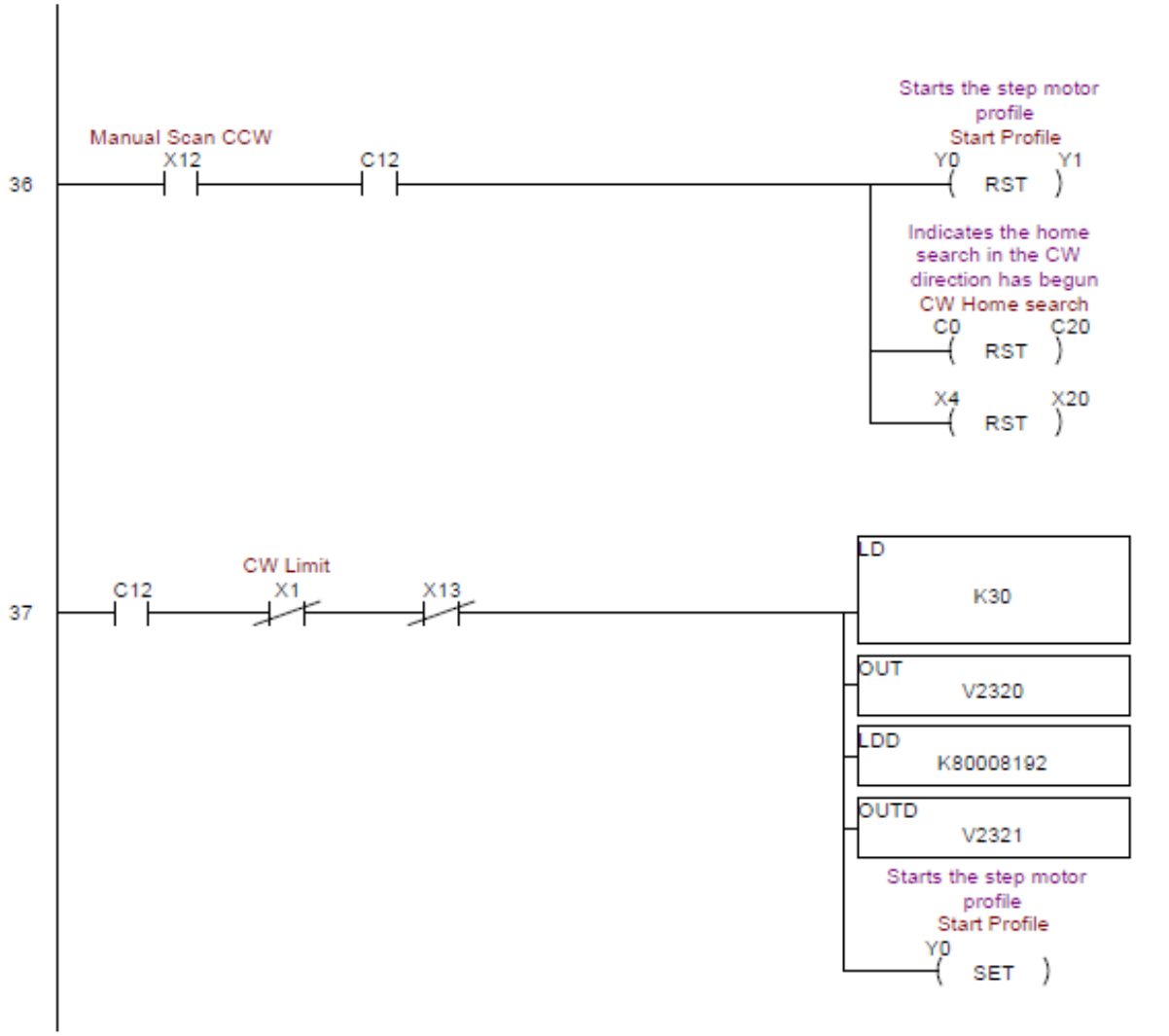

Indicates the home search in the CW direction has begun
CW Home search
C0
CW limit switch
CW Limit reached
C1
CW Limit
X1
Starts the step motor profile
Start Profile
Y0
19
RST
LDD
K80000300
OUTD
V2321
CW limit switch
CW Limit reached
C1
SET
CW limit switch
CW Limit reached
C1
TMR
Delay mtr rever0
T0
K25
20
set after slight delay from T0
CCW delay done
C2
Delay mtr rever0
T0
21
SET
Starts the step motor profile
Start Profile
Y0
SET
A
set after slight delay from T0
CCW delay done
C2
CCW past home
C3
Center of travel homing sensor
Home Sensor
X2
22
A
CCW past home
C3
SET

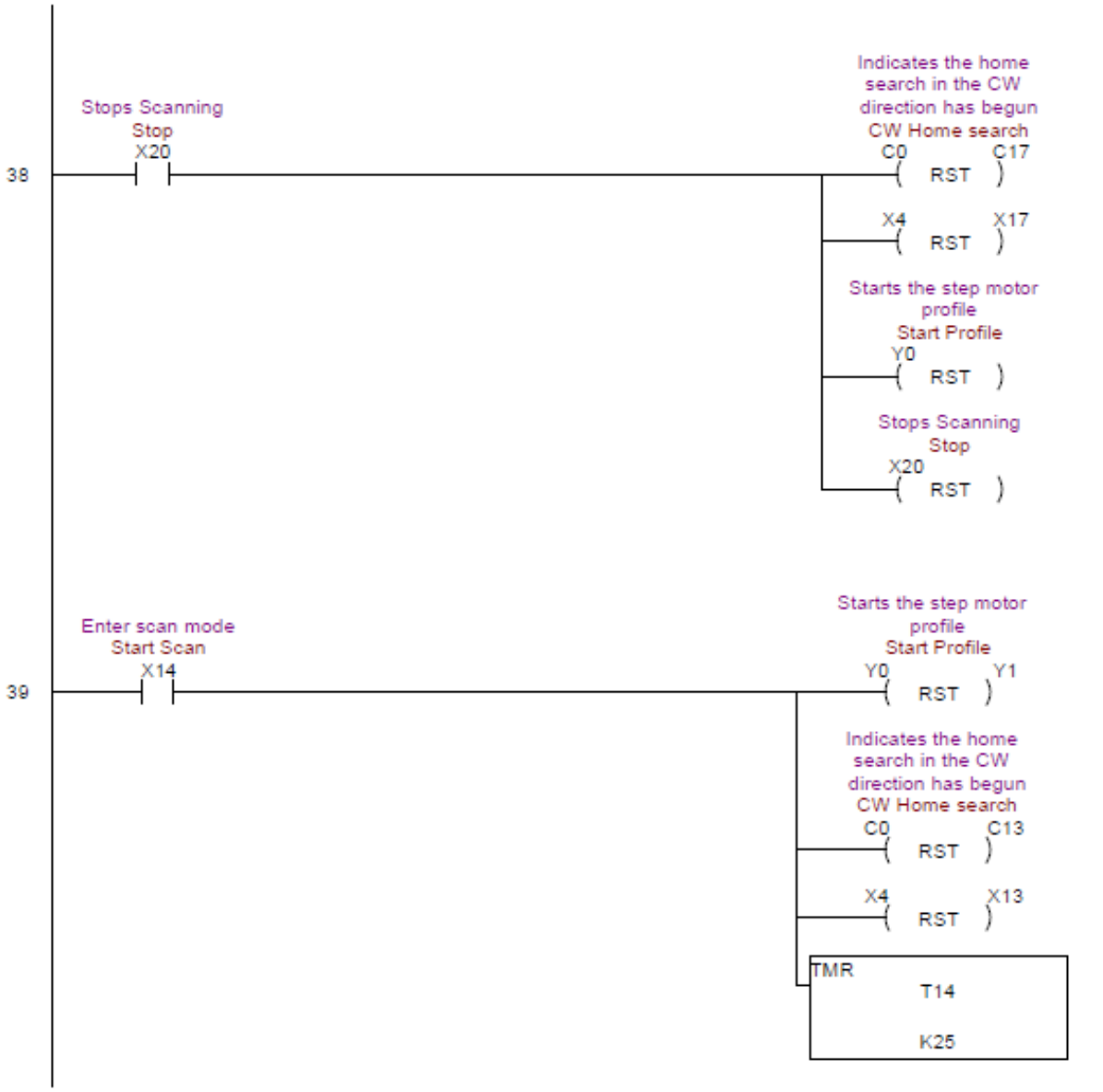

23
CCW past home
C3
Center of travel homing sensor
Home Sensor
X2
Starts the step motor profile
Start Profile
Y0
RST
LDD
K30
OUTD
V2321
T1 Start
C4
SET
24
T1 Start
C4
TMR
Delay mtr rever1
T1
K25
25
Delay mtr rever1
T1
T1 Done
C5
SET
Starts the step motor profile
Start Profile
Y0
SET
A
26
Indicates the home search in the CW direction has begun
CW Home search
C0
CW limit switch
CW Limit reached
C1
CCW past home
C3
Center of travel homing sensor
Home Sensor
X2
T1 Done
C5

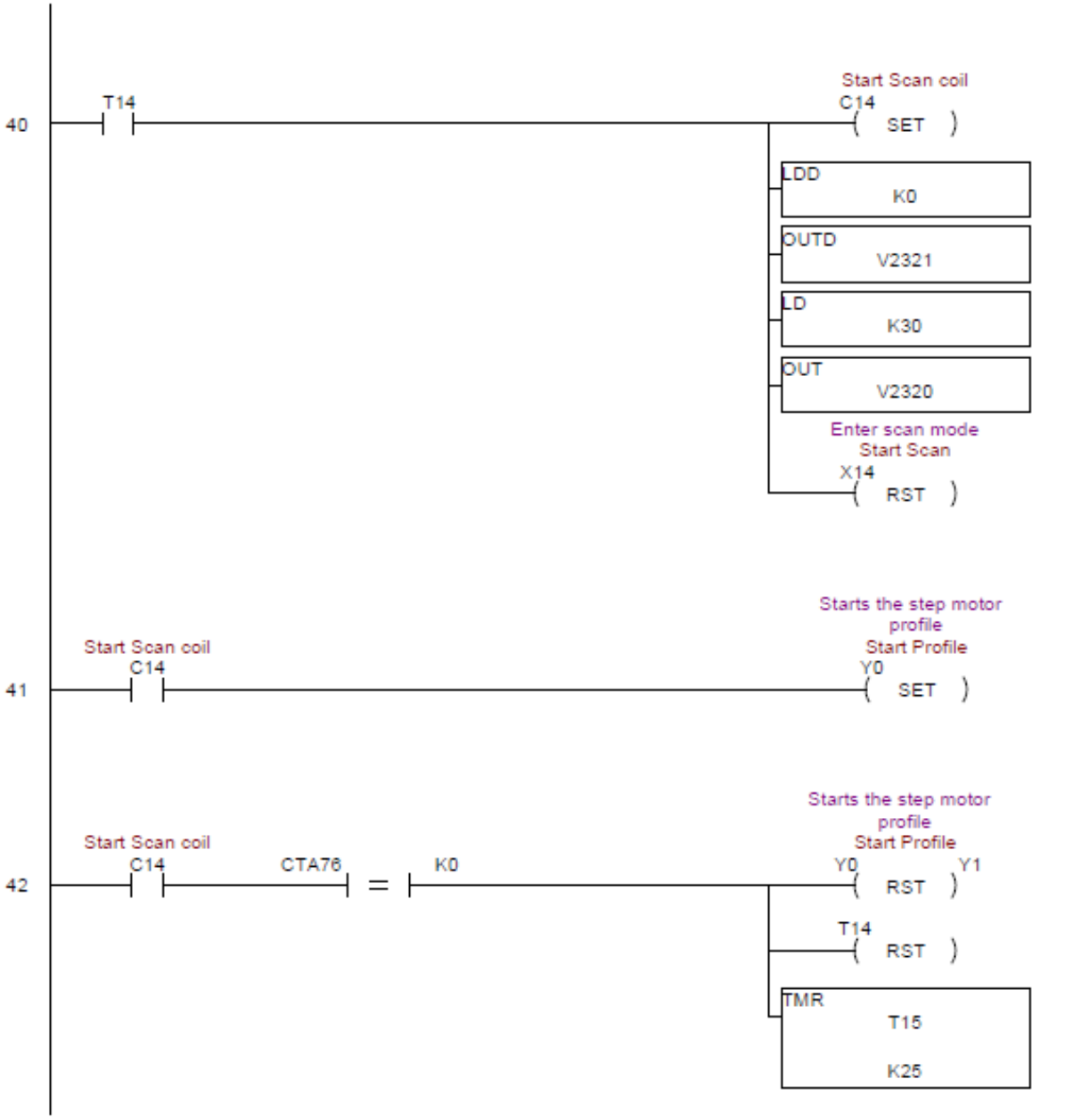

Starts the step motor profile
Start Profile
Y0
RST
C23
SET
Indicates the home search in the CW direction has begun
CW Home search
27
C23
C0
C20
RST
X4
X20
RST
Starts the step motor profile
Start Profile
Y0
Y1
RST
TMR
T2
K15
28
T2
LDD
K0
OUTD
CTA76
Direction
Y1
PD
TMR
T5
K5
29
T5
C23
RST

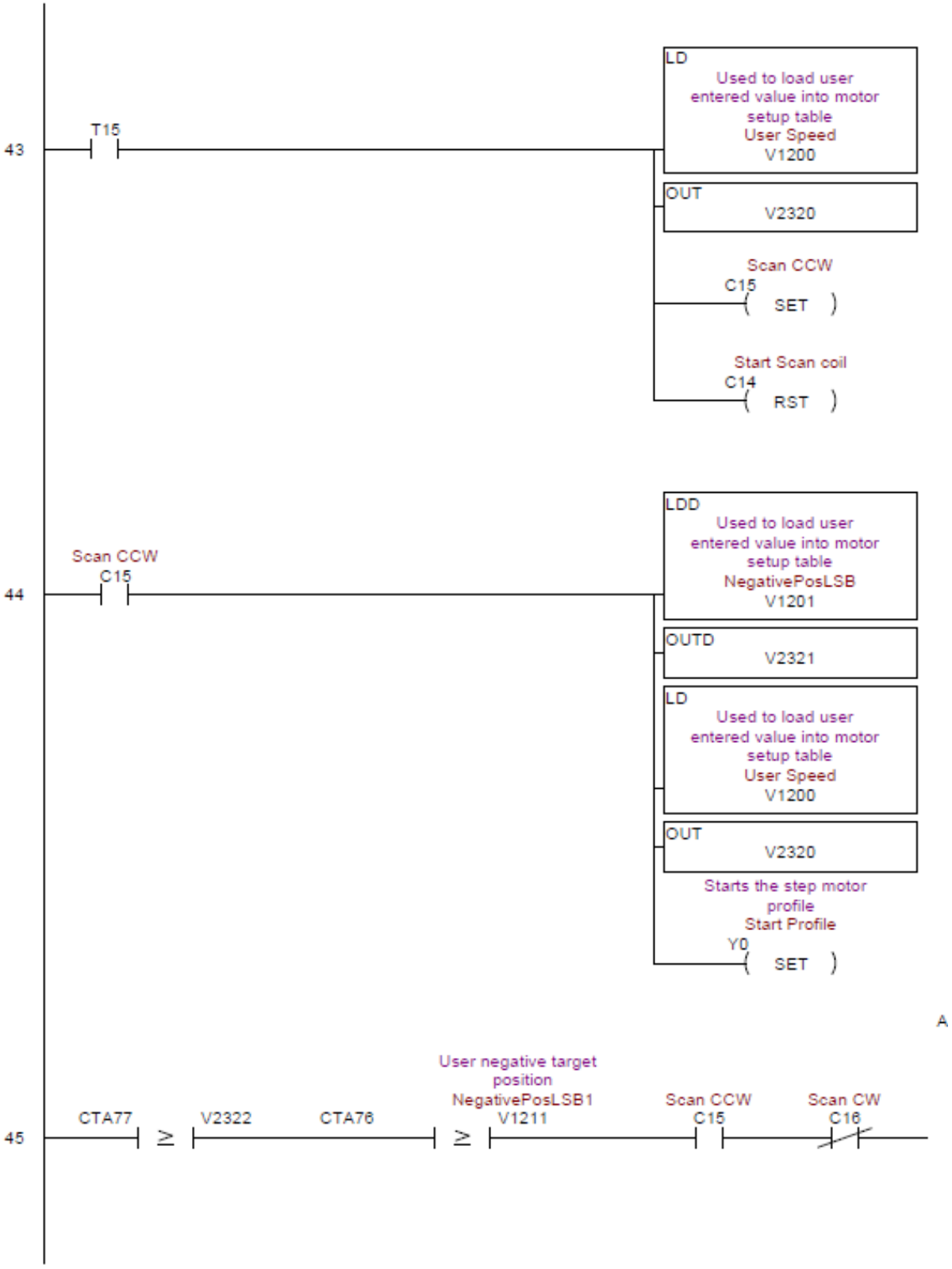

Starts the step motor profile
Start Profile
Manual Scan CW
X11
C11
30
Y0
Y1
RST
X4
X10
RST
Manual Scan CCW
X12
X20
RST
Indicates the home search in the CW direction has begun
CW Home search
C0
C10
RST
C12
C20
RST
TMR
T11
K40
T11
31
C11
SET
Manual Scan CW
X11
RST
Starts the step motor profile
Start Profile
Manual Scan CW
X11
C11
32
Y0
Y1
RST
Indicates the home search in the CW direction has begun
CW Home search
C0
C20
RST
X4
X20
RST


33
C11
CCW Limit
X0
X13
LD
K30
OUT
V2320
LDD
K8192
OUTD
V2321
Starts the step motor profile
Start Profile
Y0
SET
34
Manual Scan CCW
X12
C12
Starts the step motor profile
Start Profile
Y0
Y1
RST
X4
X11
RST
X13
X20
RST
Indicates the home search in the CW direction has begun
CW Home search
C0
C11
RST
C13
C20
RST
TMR
T12
K40
35
T12
C12
SET
Manual Scan CCW
X12
RST

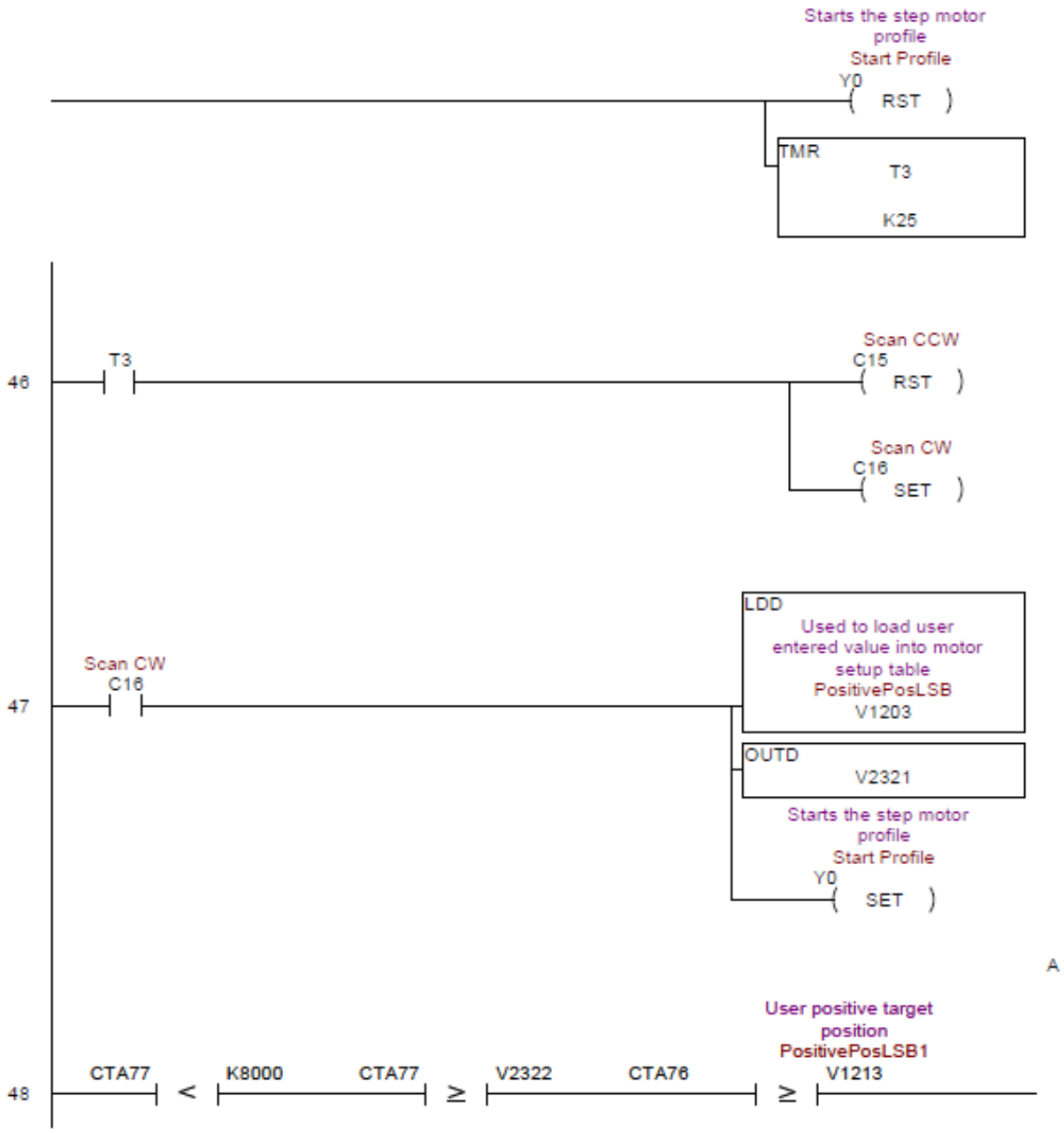

Starts the step motor profile
Start Profile
Manual Scan CCW
X12
C12
Y0
Y1
36
RST
Indicates the home search in the CW direction has begun
CW Home search
C0
C20
RST
X4
X20
RST
CW Limit
C12
X1
X13
37
LD
K30
OUT
V2320
LDD
K80008192
OUTD
V2321
Starts the step motor profile
Start Profile
Y0
SET

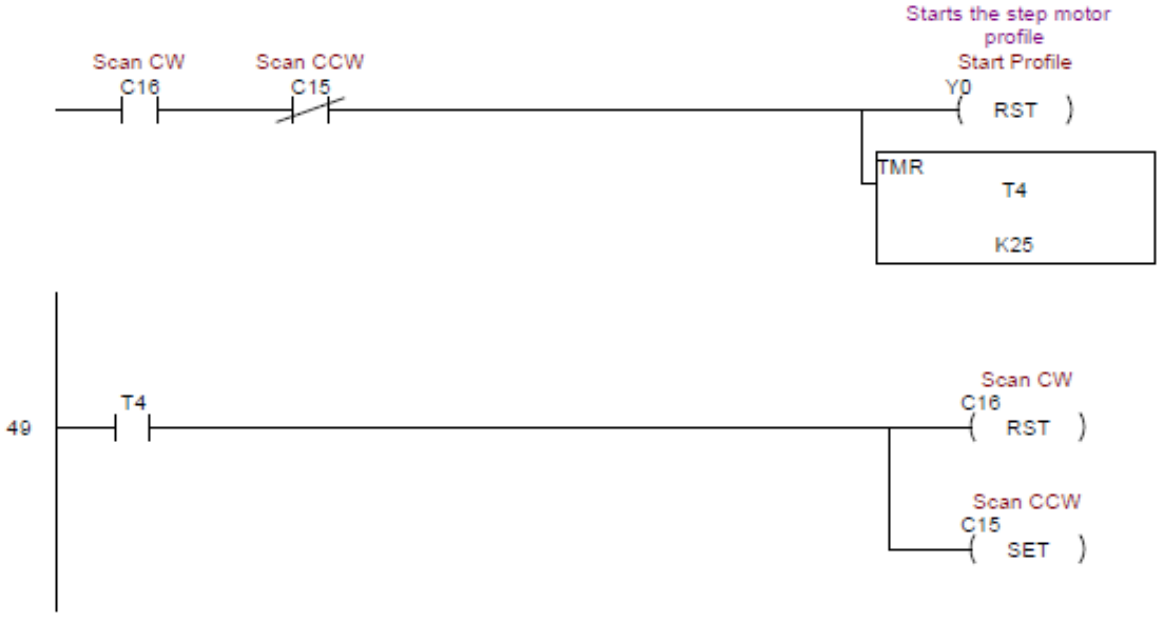

38
Stops Scanning
Stop
X20
Indicates the home search in the CW direction has begun
CW Home search
C0
C17
RST
X4
X17
RST
Starts the step motor profile
Start Profile
Y0
RST
Stops Scanning
Stop
X20
RST
39
Enter scan mode
Start Scan
X14
Starts the step motor profile
Start Profile
Y0
Y1
RST
Indicates the home search in the CW direction has begun
CW Home search
C0
C13
RST
X4
X13
RST
TMR
T14
K25

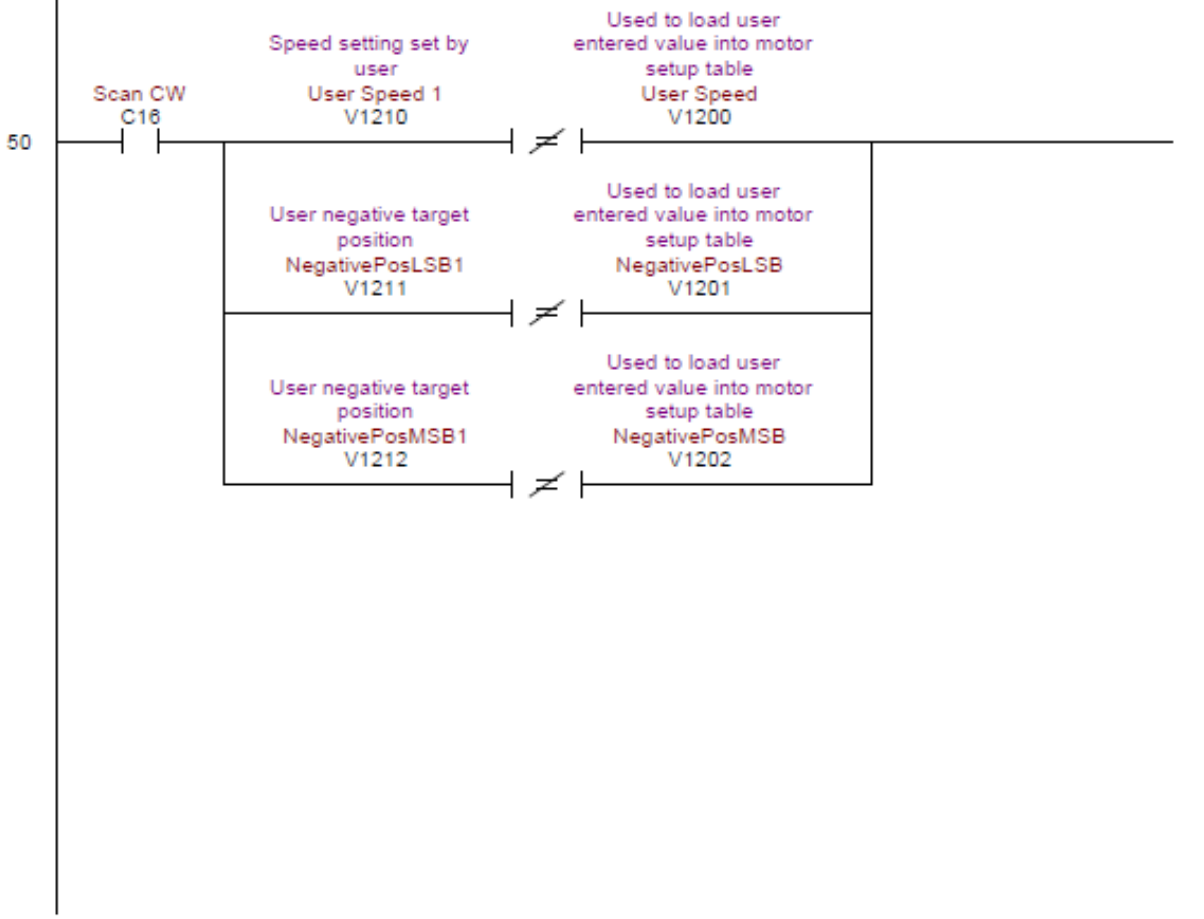

40
T14
Start Scan coil
C14
SET
LDD
K0
OUTD
V2321
LD
K30
OUT
V2320
Enter scan mode
Start Scan
X14
RST
41
Start Scan coil
C14
Starts the step motor profile
Start Profile
Y0
SET
42
Start Scan coil
C14
CTA76
=
K0
Starts the step motor profile
Start Profile
Y0
Y1
RST
T14
RST
TMR
T15
K25


43
T15
LD
Used to load user entered value into motor setup table
User Speed
V1200
OUT
V2320
Scan CCW
C15
SET
Start Scan coil
C14
RST
44
Scan CCW
C15
LDD
Used to load user entered value into motor setup table
NegativePosLSB
V1201
OUTD
V2321
LD
Used to load user entered value into motor setup table
User Speed
V1200
OUT
V2320
Starts the step motor profile
Start Profile
Y0
SET
A
45
CTA77
≥
V2322
CTA76
User negative target position
NegativePosLSB1
≥
V1211
Scan CCW
C15
Scan CW
C16

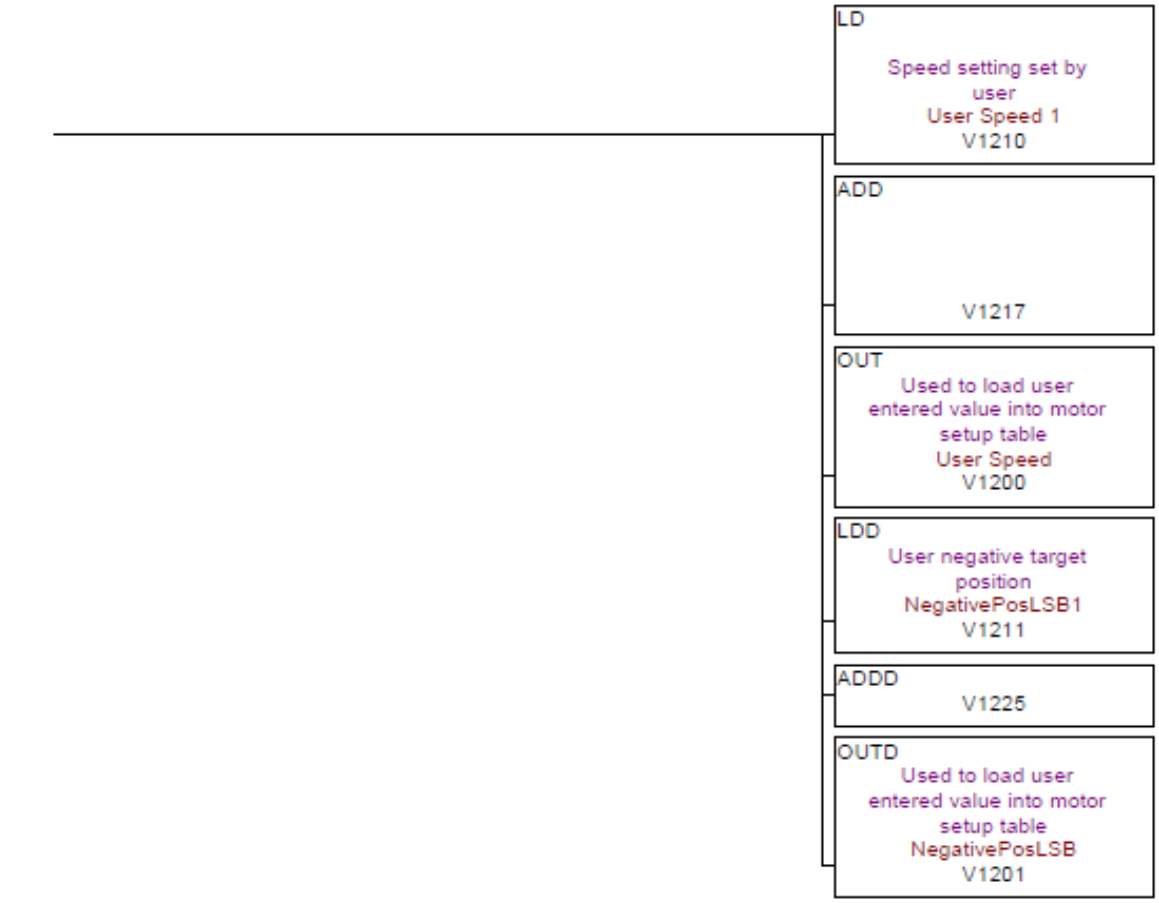
A


Starts the step motor profile
Start Profile
Y0
RST
TMR
T3
K25
46
T3
Scan CCW
C15
RST
Scan CW
C16
SET
47
Scan CW
C16
LDD
Used to load user entered value into motor setup table
PositivePosLSB
V1203
OUTD
V2321
Starts the step motor profile
Start Profile
Y0
SET
A
User positive target position
PositivePosLSB1
V1213
48
CTA77
<
K8000
CTA77
≥
V2322
CTA76
≥

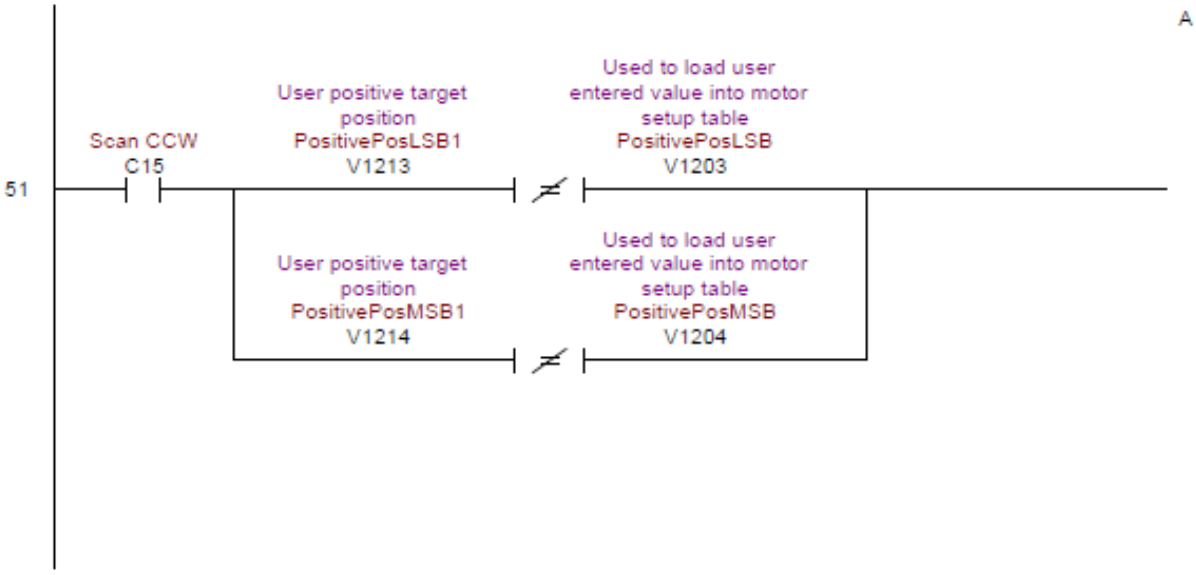

Starts the step motor profile
Scan CW
C16
Scan CCW
C15
Start Profile
Y0
RST
TMR
T4
K25
49
T4
Scan CW
C16
RST
Scan CCW
C15
SET

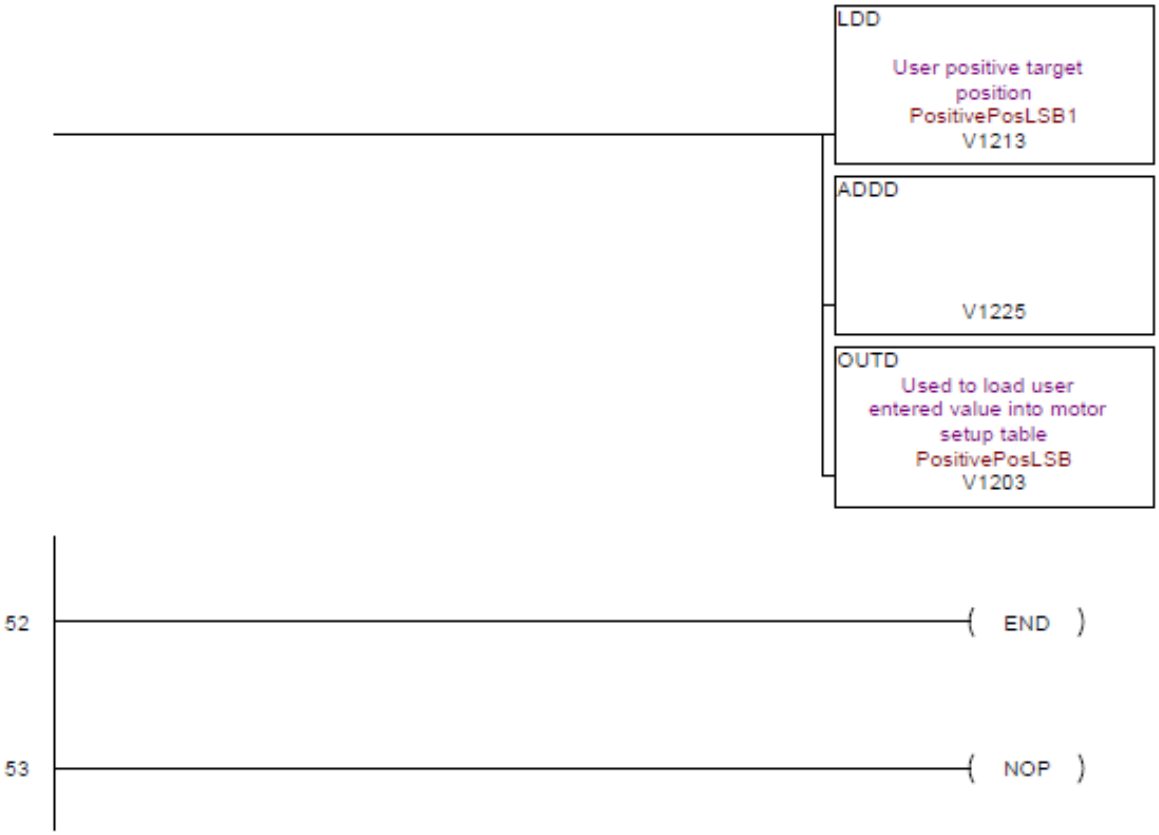

50
Scan CW
C16
Speed setting set by user
User Speed 1
V1210
Used to load user entered value into motor setup table
User Speed
V1200
User negative target position
NegativePosLSB1
V1211
Used to load user entered value into motor setup table
NegativePosLSB
V1201
User negative target position
NegativePosMSB1
V1212
Used to load user entered value into motor setup table
NegativePosMSB
V1202

A


LD
Speed setting set by user
User Speed 1
V1210
ADD
V1217
OUT
Used to load user entered value into motor setup table
User Speed
V1200
LDD
User negative target position
NegativePosLSB1
V1211
ADDD
V1225
OUTD
Used to load user entered value into motor setup table
NegativePosLSB
V1201

A


51
Scan CCW
C15
User positive target position
PositivePosLSB1
V1213
Used to load user entered value into motor setup table
PositivePosLSB
V1203
User positive target position
PositivePosMSB1
V1214
Used to load user entered value into motor setup table
PositivePosMSB
V1204


LDD
User positive target position
PositivePosLSB1
V1213
ADDD
V1225
OUTD
Used to load user entered value into motor setup table
PositivePosLSB
V1203
52
END
53
NOP